THE MODERN MOTOR ENGINEER

A PRACTICAL WORK ON THE MAINTENANCE,
RUNNING, ADJUSTMENT, AND REPAIR OF
AUTOMOBILES OF ALL TYPES, AND ON THE
MANAGEMENT OF GARAGES

BY

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PREFACE

The present edition, which is the fifth to be published since the original one of 1927, has been thoroughly revised and largely re-written, in order to bring it up to date with the latest motor engineering practice. At the time of preparation of the last edition most of the motor cars in current use were either pre-1939 ones or modified designs based upon the latter types. Since then, entirely new designs have been produced by all the leading car manufacturers, primarily with the export market as their objective, but also to fill part of the demand for new models in this country.

The present work was therefore planned to deal with these models, but at the same time to retain certain matter relating to basic principles which it was believed would be of particular value to the reader seeking a sound knowledge of motor vehicle servicing, maintenance and adjustment.

It may here be mentioned that in the revision of this work over 800 new diagrams and photographic reproductions have been used.

Of particular importance to the motor engineer is the subject of tools and servicing equipment. For this reason a good deal of information has been added and earlier equipment either deleted or revised, so that modern tools and equipment covering a wide range of application in motor vehicle maintenance and overhaul are illustrated and their applications described in various parts of these volumes.

In view of the relatively large number of cars and commercial vehicles now in service it is not possible, even in a work of the present proportions, to include accounts of the dismantling, servicing and overhaul, reassembly and adjustment of the various chassis members, e.g. the engine, transmission, brakes, suspension and steering systems, of every make of vehicle, since a complete volume could easily be devoted to each model. In order to give as much information as possible the plan here adopted is to describe the general principles and methods in every instance, and then to give one or more typical examples from modern car or vehicle practice. With this knowledge the motor engineer and mechanic should be able to examine other designs and understand how to deal with these from the maintenance and servicing points of view.

Whilst it is not possible to mention in detail the wide range of the present revision, the following important examples of new or entirely re-written sections may be singled out, namely: Motor Engineering

Measuring Devices; The Crank Shaft, Flywheel and Oil Seals; Cylinders and Liners; Engine Lubrication System; Fuel System and Carburettor; Motor Garage Layout; Garage Machine Shop Equipment; Lubrication of Motor Vehicles; Automobile Repair Costing and Accounts; Fabricating Sheet-metal Components; Motor Bodywork Repairs; Independent Wheel Suspension; Brakes; Automobile Electrical Circuits and Car Radio.

In addition, the chapter dealing with the Legal Aspects concerned with motor vehicles has been revised and the latest regulations dealt with. A fairly complete list of existing Official Motor Regulations issued by the Ministry of Transport, with their prices, is another special feature of this new edition.

When the very wide existing field of motor vehicle servicing subjects is considered, it will be understood that it has not been possible to cover every aspect of each model in the present volumes, but the reader may, here, be reminded that he is able to obtain any specialised information on motor engineering subjects coming within the scope of this work through the "Modern Motor Engineer" Information Bureau Service, for which purpose twelve coupons are presented with each set of volumes. To those concerned with the maintenance and servicing of the electrical equipment of motor vehicles of all kinds, in addition to the detailed information given in Volume IV, the practically complete set of full-page electrical circuit diagrams and the data given in Volume V of this Work, we believe will prove of much value. Similarly, the individual vehicle data sheets in the same volume will enable the motor engineer, when servicing various cars and commercial vehicles, to check the various dimensions, sizes, angles and other relevant values for each and every make of vehicle.

In conclusion, we should like to take this opportunity of expressing our appreciation to the various firms and individuals who have co-operated in the preparation of many of the chapters of this Work, in particular to Messrs. Austin Motor Co. Ltd., Morris Motors Ltd., Standard Motor Co. Ltd., Vauxhall Motor Co. Ltd., Hillman Motor Car Co. Ltd., Humber Ltd., Sunbeam Talbot Ltd., E. P. Barrus Ltd., Black & Decker Ltd., Delco-Remy & Hyatt Ltd., and Messrs. Joseph Lucas Ltd.; and to Messrs. W. Cooper, H. H. Jones and D. Lewis-Jones for the chapters contributed by them.

A. W. Judge.

Farnham, Surrey.

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THE MODERN MOTOR ENGINEER

VOL. I

CHAPTER I

INTRODUCTORY

THE comparatively rapid growth of the automobile in the present century has resulted in the development of establishments all over the country for the maintenance, servicing, and overhaul of motor vehicles. Unlike most other branches of engineering that have extended at a much lower rate of progress, and have therefore settled down to standard methods and equipment, the motor industry has experienced several interesting development phases, some of which have not been entirely satisfactory from an engineering viewpoint. Thus the early motor-cars and motor-cycles were produced and sold before there were sufficient qualified engineers capable of maintaining and repairing them, so that it fell to the lot of the cycle repairer to do this work. In other instances, and at a somewhat later period in the history of the automobile, petrol and oil stations and small garages undertook the servicing of motor vehicles, although there was a scarcity of trained mechanics for this special branch of engineering work. Frequently, all the experience available was that of cycle repairing, so that the motoring public were the sufferers in connection with the upkeep and repair of their vehicles.

Fortunately, the day of the cycle repairer, shop labourer, and petrol and oil salesman has come to an end, and in their place there is now a very considerable number of motor engineers and mechanics available for the efficient servicing and overhaul of all types of motor vehicle. On the other hand, there is, unfortunately, a certain proportion of garage employees who have served no apprenticeship, having in many instances commenced work as boys to sweep the shop, dispense oil and petrol, and do other miscellaneous tasks. It should therefore be stressed that the serving of an apprenticeship to motor engineering is essential—and this necessitates at least four years' instruction in a recognised motor-engineering works or modern garage and repair shop.

In all that follows in the present work it has been assumed that the reader is a complete mechanic—not necessarily a motor mechanic—who is able to use engineering tools satisfactorily, file surfaces flat, scrape flat and round surfaces correctly, and, in general, possess the qualifications of the metal craftsman or engine fitter. He should know how to solder and braze metals, but need not know much about welding, as this is a specialised trade. A further essential is that the mechanic must be able to use precision measuring instruments such as the engineer's rule, callipers, vernier callipers, micrometer, and dial gauge.

There is yet another very important qualification for the motor mechanic, namely, that he must be conversant with the elementary theory and working of (1) the petrol engine, (2) the modern carburettor, (3) the ignition system, (4) the transmission or car mechanism. It is not necessary for him to have the deeper knowledge of the student, draughtsman, and designer, but a sufficient insight into the general working principles to enable him to understand clearly the functions of the various components that he may be called upon to adjust, service, or repair.

It is not the purpose of the present work to instruct the reader in the theory of the petrol or diesel engine, or of the mechanism of the car, although a certain amount of data and information are given in these volumes, so that in what follows it is assumed that he is not only a practical mechanic but also knows what happens inside the engine and how the transmission, steering, and braking systems work. It may here be added, for the benefit of those readers who may not have been fortunate enough to have had the opportunity of studying the theory and practice of automobiles, that several good textbooks are now available on this subject, and we shall at all times be pleased to advise readers on the best books of references for their purpose. In this way those with practical mechanical skill and knowledge can become conversant with automobiles, and thus undertake various kinds of jobs upon these vehicles.

Having emphasised the importance of practical mechanical skill and knowledge, and the necessity of an acquaintanceship with the general theoretical principles, it may be stated that anyone with these qualifications can undertake automobile maintenance, servicing, and repair work if he has the proper tools and equipment for the work.

What the Owner-driver can Undertake

Before proceeding to discuss the equipment and scope of the work that the modern motor garage can undertake, it is proposed to consider the nature of the jobs that the mechanically-minded car owner or the private car chauffeur can undertake satisfactorily with the ordinary private garage limitations. Assuming that he has the necessary small tools, e.g. spanners, screwdrivers, pliers, hammer, files, feeler gauges, etc., it is quite possible and satisfactory for him to maintain his motor-car in good running condition, provided he has a copy of the Owner Manual for the car in question and the car itself is in mechanical order.

If the car has been purchased new it will be supplied with the necessary kit of tools and Owner Manual. The owner should read through the latter volume carefully, making sure that he understands not only the illustrations but also the corresponding text matter and instructions. In particular he should make himself familiar with the lubrication instructions, which are usually illustrated by means of diagrams that can readily be understood.

Apart from the maintenance of engine and transmission lubrication by attention to the various lubricating points at the recommended periods and with the correct grades of lubricants, the owner should be able to undertake the following maintenance work:

(1) *The Power Unit.*—Adjust the valve-tappet clearances. Adjust the sparking-plug gaps. Adjust the contact-breaker gap, cleaning contacts, if necessary, beforehand. Decarbonise the combustion chambers. Grind in the inlet and exhaust valves. Check and, if necessary, adjust the ignition timing. Adjust the carburettor slow-running control. Drain the oil sump, clean the filters, and replenish with fresh oil. Check action of fuel-feed pump. Clean carburettor air filter. Drain and flush out cooling system.

(2) *The Transmission.*—Adjust clutch, by means of stop or other adjustment provided, for correct pedal movement.

[*Note.*—Adjustments to gearbox, propeller shaft, and back-axle unit are the work of the service engineer, since these items require special knowledge and the use of the manufacturer's tools and equipment.]

(3) *The Braking System.*—Adjust to take up effects of brake lining wear according to the manufacturer's instructions.

[*Note.*—Brake-lining renewal and brake-drum truing are usually beyond the skill or scope of the owner-driver.]

(4) *The Suspension System.*—In some instances provision is made for taking up the effects of spring shackle side wear.

Shock absorbers should be "topped up" if of the hydraulic pattern, and the unit adjusted to give the best road springing action, according to the manufacturer's instructions.

Springs, if of the leaf type, should be kept clean, sprayed with a penetrating oil if squeaky, and lubricated when necessary.

(5) *The Steering System.*—Adjust steering gearbox end play in steering column and in the cross shaft, as described in the Owner Manual.

Check and if necessary rectify amount of front-wheel "toe-in." Usually it is not possible, without special gauges and equipment, to check or correct the front-wheel camber, castor, and king-pin angles.

(6) *The Electrical System.*—In addition to the maintenance of the sparking plug and contact breaker and the checking of the ignition timing, mentioned under "The Power Unit," the intelligent owner can clean the commutator and brushes of the dynamo, changing and bedding in new brushes if necessary. He can—with the aid of the Manual—adjust the voltage-control regulator and cut-out, maintain the battery, adjust the electric horn, and focus and adjust the car's headlamps. The direction indicators can also be maintained (lubrication and bulb replacement). Cable connections can be kept clean and tight and faulty cables replaced.

(7) *Miscellaneous Items of Attention.*—All important chassis-fixture nuts, e.g. those of the engine mountings, gearbox, radiator, motor-car body, etc., should be checked for tightness at regular (but usually long) intervals.

Cylinder head inlet and exhaust manifold nuts should be checked, door hinges lubricated, and door stops adjusted to prevent noise. Tyres should be maintained at correct pressures and kept clean. Body-work and wings should be maintained in good condition, so far as is possible.

It will be noted from the preceding considerations of the items of maintenance that all of these can be undertaken with the aid of the ordinary car's tool kit. This, of course, includes the motor jack, as it is necessary to elevate the wheels clear of the ground for any steering or braking adjustments, although in some designs the brake shoes can be adjusted with the wheels on the ground.

If the manufacturer's maintenance instructions are carefully observed there is no reason why a car should not run satisfactorily over a period of 25,000 to 40,000 miles before major repairs or replacements become necessary. Even so, it is possible for the owner-driver, if he has had practical mechanical experience, to undertake certain repairs and renewals, but it is then necessary to have a suitable garage-workshop fitted with bench, vice, grinder, sensitive drilling machine, small lathe, and some special tools and equipment.

The Garage Workshop

With the aid of the minimum machine and tool equipment mentioned previously, the owner-mechanic can undertake such operations as follows, namely: removal of worn piston rings and fitting of new ones, if the cylinders are not worn appreciably, fitting of new small-end bushes and gudgeon pins, fitting of new valves, removal and renewal of king-pin bushes, making or truing of valves, making of new pins and heat-treatment of these for various chassis and control eye and fork-end members, making special washers, screws, bolts, and nut members, truing of worn dynamo and motor commutators, remetalling and machining of big-end and main bearings if of the solid white-metal as distinct from the half-shell types, extraction and insertion of ball and roller bearings, cleaning out gudgeon-pin holes in pistons and fitting of new gudgeon pins, fitting new piston rings, etc. The skilled owner-mechanic can readily deal with such work as the dismantling of the smaller makes of car engines, decarbonising of cylinder heads, regrinding of valves and seatings, taking up of the wear in solid-pattern white-metalled big-end and main bearings, taking up play in the steering mechanism, checking front-wheel alignment, diagnosis of engine, transmission and electrical troubles, minor body repairs—such as the removal of dents in mudguards, minor radiator (soldering) repairs, tyre and tube minor repairs—such as cuts in treads and punctures, and a host of other car repairs and adjustments.

There are, however, many operations necessitating the use of expensive equipment and skilled or trained operators which are necessarily outside the scope of the owner-mechanic. Typical instances of these include the truing of worn cylinder bores, making of pistons and rings, welding repairs to broken or cracked members, rebuilding of dynamos and motors, regrinding of worn crankshaft journals (although hand-truing equipment can be used by the operator), vulcanising repairs of a more involved nature, car bodywork repairs, building up of worn metal parts and machining of some, making of special gears, forgings, and similar items to replace broken or worn parts. There are, of course, numerous other motor-engineering operations involving special knowledge, skill, the use of precision measuring devices, and various machines, plant, and equipment that are beyond the resources of the garage-workshop operator.

It can, however, be stated from a long experience and association with keen owner-drivers, many of whom were mechanics or mechanically trained, that a surprisingly large number of automobile repair, reconditioning, and maintenance operations can be dealt with by those of exceptional keenness and skill. Thus one has noted the satisfactory reconditioning of worn cylinder barrels, making of new pistons and rings, truing of big-end and main crankshaft journals, minor repairs to cracked castings by brazing, soldering, or pegging operations, gearbox overhaul, back-axle overhaul, relining of brake shoes, complete rewiring of motor vehicles, electrical testing of dynamos and motors, regulators, and cut-outs, and rewinding of the faulty components, battery plate repairs or renewals, and various other more complex processes. In most cases temporary equipment or machine fittings and accessories have been devised to do the work in question. The underlying motives in such cases have been those concerned with economy in cost, the time or convenience factor, and making a hobby of this branch of engineering work.

The Use of Spare Motor Components

It is a big advantage for those who undertake their own maintenance and repair work that it is possible to purchase from the actual car manufacturers spare parts of practically every component of their cars and at a price that makes it quite uneconomical for anyone to make single components. The fact that the manufacturer's parts are made on a mass-production basis implies that they can be machined at a far lower cost than is possible for a few such parts. Moreover, they are produced from the most suitable metals, and if of certain grades of steel are heat-treated in automatic furnaces and tempering baths in a manner beyond the scope of the owner-mechanic. Again, there is the question of dimensional accuracy and finish, both of which are of a high degree and uniform for all similar components.

It will therefore be apparent that it almost invariably pays to purchase spare parts rather than to make these in the garage (home or commercial) workshop.

Perhaps the greatest advantage to the owner-mechanic in being able to use spare parts for his repair operations is that, since his own services or labour are free, the cost of the job is usually only that of the spare parts and other materials used. When this work is undertaken by the commercial garage, however, the labour costs are often many times the cost of the component, so that the total cost may be relatively high. By doing the dismantling, fitting, and reassembling work himself, the owner-mechanic can thus save much expense, and at the same time have his car on the road again more expeditiously than if it had been taken to the local garage to take its turn with other repair work.

It may here be asked why in the preceding section this aspect of motor-repair work was not mentioned. The principal reason for this was that in many cases of earlier motor-vehicle models the spare parts are not available; in some instances this is due to the fact that the vehicle is no longer made and the firm has gone out of existence. In other examples, where the repair is of much urgency or the component is of a relatively simple nature or can be made from a component taken from another vehicle, it is often advisable to undertake the making of such parts rather than to purchase them. Again, it is now possible to use worn components, since these can be built up with metal over the worn surfaces by electro-deposition or metal-spraying processess, and then machined to size. Thus one can use a crankshaft having badly worn journals again by adopting this expedient. Another instance in which it certainly pays to recondition the existing part or unit rather than to replace it with a new one is that of the cylinder block or head. When cracked, welding repairs, followed by subsequent machining operations, if skilfully executed, will give results comparable to those of new blocks or heads. Further, if valve seatings are badly worn and can no longer be reconditioned by the usual grinding methods, the seatings can be built up by welding suitable alloy on to them and then machined to give seatings similar to those of the original new engine. Broken crankshafts can also be repaired by the electric-arc welding method, and there are to-day many examples of such crankshafts which have given long service after repair.

When Spare Parts are Unobtainable

It has already been stated that motor components can usually be made in the garage-workshop or machine shop, or the worn components can be reconditioned by metal deposition methods in instances where no spares are available. There is, however, another alternative available to the owner-mechanic in particular and the motor engineer in general, namely, that of using spare parts taken from dismantled cars or commercial vehicles, if necessary reconditioning such parts to render them serviceable again.

The car breaker's yard or old car dump is a fruitful source of supply for components that can no longer be obtained by other methods, and in this respect the advertisement columns of motoring journals frequently refer to early makes of cars that are being dismantled for the purpose of their components. Usually, parts taken from scrapped vehicles can be purchased for a fraction of the cost of new ones, and in most instances will give good service in similar makes of vehicles kept on the roads.

It is here necessary to mention a word of warning concerning the use of certain *severely stressed components*, such as the half-axle components of the rear-axle unit, gearbox, and back-axle gears and crankshafts. After many years of hard usage the metal of such steel parts is liable to become weakened by a process known as *fatigue*, whereby the structure of the metal becomes modified and weakened, with the result that sooner or later the component will fracture in service; a typical example is that of the previously mentioned back-axle half-shafts, which are subjected to severe and constantly changing stresses that eventually may cause fracture whilst in use.

Economical Repairs by Welding Methods

It should be borne in mind by the motor engineer, as briefly mentioned earlier, that serious fractures to parts such as the engine cylinder block, crankcase, gearbox casing, back-axle casing, and similar parts, do not now necessitate the scrapping of these expensive parts, for automobile welding-repair methods have attained such a high standard of satisfaction that absolutely reliable repairs can be effected often at a fraction of—and always below—the cost of a new part. It is not necessary to purchase a new stub axle to replace one which has been worn through a ballrace revolving, or a rear-axle casing which has worn thin for a similar reason, nor is it necessary to obtain a new propeller shaft or crankshaft in place of a broken one. In the former cases the worn parts can be built up with new metal by welding or electro-deposition methods, afterwards being machined to proper size. In the latter cases scientific welding methods enable badly fractured shafts and power-transmitting members to be rewelded, machined, and ground so that in strength and accuracy they are equal to new. Moreover, there is always the knowledge that the repaired member will fit, and that its bearings, studs, bolt holes, machined surfaces, etc., are usually just as good as before the fracture. In one of the sections of this work, a detailed account is given of welding repairs.

Work Undertaken by the Motor Garage

Having considered the possible range of work that may be undertaken in the owner-mechanic's workshop and in the ordinary commercial garage in a general sense, it is now necessary to review the various kinds of operations, repairs, maintenance, and overhauls that come within the scope of the modern motor garages, from the smaller to the larger establishments.

This information is considered essential, since it is only with a knowledge of the scope of the garage's activities that the motor engineer can plan and equip his buildings satisfactorily so as to be in a position to deal with each and every phase of motor maintenance and repair work that may arise.

It should here be mentioned that in dealing with the general aspects of the work that is undertaken by the motor garage it is not intended to deal with the sales side of the subject, e.g. the selling of petrol, lubricants, accessories, tyres, etc., nor with the equipment concerned with these expendable items. The only exception that will here be made is that of *tyre inflation*, since this involves the use of special equipment for the supply of compressed air.

The scope of the modern motor garage and its repair shops includes work which can be divided into three separate and distinct headings, namely, as follows:

(1) The general maintenance of motor vehicles from the new condition until the effects of long usage become apparent.

(2) The overhaul and repair of worn vehicles.

(3) The repair of vehicles that have broken down on the road, due to road accidents or other causes.

It is now proposed to deal rather more fully with each of these main causes necessitating the attention of the motor engineer and the use of various kinds of tools and equipment.

(1) General Maintenance Work

Under normal peace-time conditions, when the supply of new cars and other motor vehicles is both liberal and regular, a considerable proportion of the time of the motor-garage mechanics is taken up in the maintenance of cars and other vehicles from the date of their receipt from the manufacturers until such time as the vehicles have experienced such usage as to bring them into the second category, namely, overhaul and repair of worn vehicles.

The general procedure in the case of a new motor-car notified as being ready for collection at the manufacturer's works is for the motor garage concerned with the ordering of the car to arrange for its collection by either one of the staff or a member of a firm that specialises in the collection and delivery of cars to various garages or individuals throughout the country. The drivers are experienced men who can usually be relied upon not to exceed the speed limits or engine revolutions for new cars that are recommended by their manufacturers.

Upon delivery at the particular garage the car is given a check-over, then washed down if necessary, the additional accessories ordered by the new owner fitted, the car registered with the county motor licensing authority, third party insurance arranged (if required by the owner) and other necessary preliminaries dealt with.

In the case of all mass-production cars the manufacturers issue essential maintenance and lubrication instructions in the Owner Manuals which are supplied with their cars. These items of maintenance attention can and often are dealt with by the owner or chauffeur, as the case may be, but on the other hand there are many owners, including women drivers, who have not the mechanical aptitude, the time, or inclination to carry out the manufacturer's maintenance instructions, so that this work is done by the local car agents at regular intervals. In most cases the manufacturers make a special arrangement with the local motor garages that act as the official agents for their cars to provide the owner with free servicing, checking over, and adjustment of the car at the end of the first 500 miles and, sometimes, again at the end of the first 1,000 miles.

Details of Free Servicing of New Cars

The nature of the servicing of cars at the end of 500 or 1,000 miles will to a large extent depend upon the actual design of the cars, so that hard-and-fast rules applicable to each and every make of car cannot be laid down. The detailed procedure will obviously depend upon the type of engine, suspension, steering, springing and braking systems, etc. It is possible, nevertheless, to obtain a good general idea of the various items of maintenance attention under the free servicing scheme if one considers a modern motor-car having the usual design and structural features of present-day accepted practice. It is therefore proposed to select a good example of a modern car in widespread use at home and abroad, so that although we cannot give servicing details of each and every make the example selected will give a useful indication of the various items of free service attention of most other makes of car. For this reason a well-known mass-produced, high-performance, popular make of car, namely the Austin A40, has been selected.

Briefly, this car is fitted with a four-cylinder overhead-valve engine of 65·48-mm. bore and 89-mm. stroke, with a capacity of 1,200 c.c. It develops 40 b.h.p. at 4,300 r.p.m. The transmission is by dry single-plate clutch through a four-speed synchromesh gearbox to a spiral bevel three-quarter-floating rear axle. The front suspension is on large helical springs, double-acting hydraulic shock absorbers being fitted. Semi-elliptic rear springs are used. A special cam steering gear of 14 to 1 ratio is fitted. Girling hydraulic brakes are used on the front wheels and mechanical brakes only on the rear wheels.

Fig. 1 illustrates the A40 chassis and shows the important items of maintenance and lettered lubrication points of attention.

The " after sales service " during the first 1,000 miles of running of the new car includes free maintenance and checking as follows:

(*a*) Changing the engine oil and checking the oil levels in the gearbox, back axle, and steering gearbox, replenishing where necessary

(*b*) Lubrication of all the chassis points provided with oil or grease nipples.

(*c*) Checking for tightness all cylinder-head joints and inlet and exhaust manifold joints.

(*d*) Checking the fan belt, tightening the latter if necessary.

(*e*) Cleaning out the carburettor float chamber and checking the slow-running adjustment. Cleaning of petrol filter.

(*f*) Examination and adjustment, if necessary, of the sparking-plug and contact-breaker points. The automatic ignition advance control should also be tested to verify if it is operating satisfactorily.

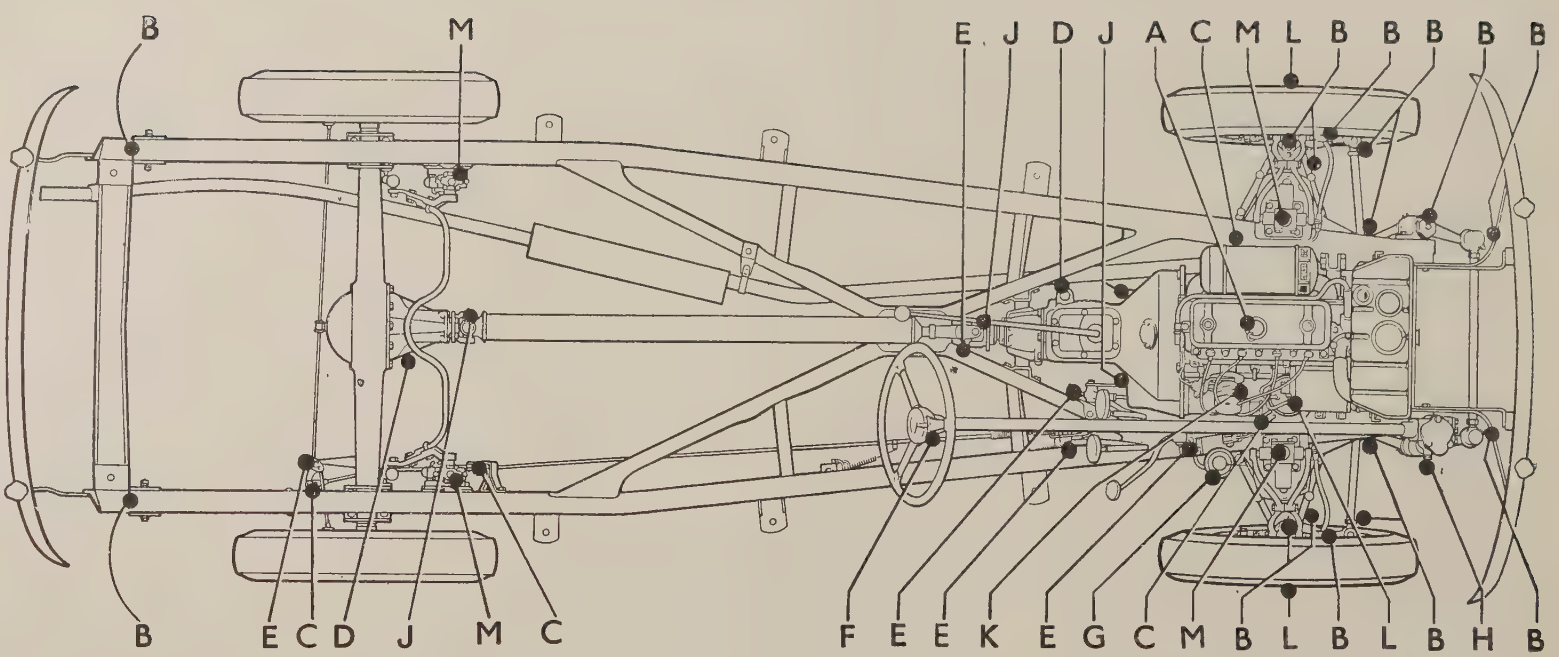


Fig. 1.—The Austin A40 Chassis Maintenance Chart.

Weekly Intervals			*Monthly Intervals*			*Occasionally*		
Medium	*Point*	*Instruction*	*Medium*	*Point*	*Instruction*	*Medium*	*Point*	*Instruction*
Oil	A	Replenish Engine Sump.	Oil	D	Draw and refill Engine Sump. Top up Gearbox and Back Axle.	Oil	H	Top of Steering Box (5,000 miles).
Oil-gun	B	Steering Connections (7). Swivel Axles (4). Front Lower Suspension Joint (2). Rear Spring Shackles (2).	Oil-gun	E	Propeller Shaft Splines (1). Brake Balance Lever (1) Handbrake Pivot (1). Clutch Pedal (2). Brake Pedal (1).	Oil-gun	J	Universal Joints (2) (1,000 miles). Clutch-operating Shaft (2) (10,000 miles).
Oil-can	C	Handbrake, Pedal and Carburettor Control Joints.	Oil-can	F	Steering Column Top Bush.	Oil-can	K	Distributor (3,000 miles).
			Examine	G	Brake Fluid Tank Level. Front Shock Absorber Fluid Levels.	Grease	L	Front Hubs (5,000 miles). Dynamo (10,000 miles) with Petroleum Jelly or H.M.P. Grease.
						Examine	M	Rear Shock Absorber Fluid Levels (5,000 miles).

(*g*) Checking the front-wheel alignment.
(*h*) Examination of the steering connections.
(*i*) Checking the clearance between the clutch pedal and the footboard.
(*j*) Examination and adjustment of the braking system.
(*k*) Lubrication of body door locks, bolts, dovetails, hinge pins, seat runners on the body, etc.
(*l*) Checking the tightness of bonnet cowl to chassis, spring clips, wheel security nuts, etc.
(*m*) Testing of lamp bulbs for correct illumination.
(*n*) Checking the charging rate of the dynamo.
(*o*) Checking all electrical wiring and terminal connections.
(*p*) Examination of battery and topping up of same.
(*q*) Testing tyres and, if necessary, inflating for correct pressure.
(*r*) Checking valve-stem clearances.
(*s*) Checking ignition timing.

The last two items would be attended to during the engine unit checks.

The careful execution of these operations ensures that the new car will give full reliability and maximum performance over a long period of service before it becomes necessary to repeat the procedure.

Regular Car Maintenance

After the car has received the free servicing attention indicated in the previous section, it is, of course, necessary to maintain it at regular intervals, and in this connection it is usual for the manufacturer to state either the mileage, weekly or monthly periods at which the recommended maintenance should be effected. It is, however, more satisfactory to state the actual mileage periods, but where these are not indicated it is usual to assume that a weekly period corresponds to about 500 miles of road service and a monthly one to 2,000 miles. These periods for recommended service attention may be shortened in the case of cars used under strenuous road and weather conditions, and in this respect more frequent attention is necessary to chassis lubrication. The following are the manufacturer's recommendations concerning the maintenance attention considered essential at the intervals mentioned:

Daily Maintenance Attention

Engine.—Check the level of oil in the sump and top up if necessary to the full mark on the dip-stick. The oil filler is on the valve-rocker cover and the dip-stick is on the right-hand side of the engine. When adding oil through the valve-rocker cover pour slowly or the oil may overflow. If the engine has been running, allow a few minutes for oil to settle before checking.

Radiator.—Check the level of water in the radiator and top up if necessary. Fill to just below the top of the filler-plug thread when the engine is cold.

Fuel Tank.—Check the quantity of fuel in the tank and add upper-cylinder lubricant when necessary.

Weekly, or at 500 Miles, Maintenance

Shackle Pins.—These are on the rear ends of the rear road springs and should be given a charge of oil once a week. There are two nipples, one for each top shackle.

Front Suspension.—Apply the oil-gun to each of the lower wishbone-arm outer bearing nipples.

Swivel Axles.—Apply the oil-gun on the two nipples on each swivel axle. This is best done with the axle jacked up, since the oil is then able to penetrate to the thrust side of the bearing.

Steering Connections.—Apply the oil-gun to the steering-centre cross-tube nipples (2) and the steering-side cross-tube nipples (4) and to the swivel idler (1).

[*Note.*—The numbers in the brackets indicate the number of oil-gun nipples to each component.]

Brakes and Controls.—Oil the hand-brake gear, pedal gear, and joints, and the carburettor control joints, using the gun on nipples and the oil-can on other joints.

Wheels and Tyres.—Check the tightness of the wheel nuts and also check the tyre pressures, including the spare, using a tyre gauge, and inflate if necessary. See that all valves are fitted with valve caps and inspect the tyres for damage. Remove any flints or nails from the treads, and ensure that there is no oil or grease on the tyre, since these substances are harmful to rubber.

A tyre that loses more than 3–4 lb. per sq. in. in a week should be suspected of a puncture, but first make sure that the valve is not leaking.

Monthly, or at 2,000 Miles, Maintenance

Engine.—Drain the sump and refill with new oil. Capacity is 7½ pints (9 U.S. pints, or 4·2 litres), plus approximately 1 pint (1·2 U.S. pints, or ·56 litre) for filter.

Gearbox.—Check the level and top up if necessary. For access, lift the front carpet and remove the rubber plug on the side of the gearbox covering. The filler plug is then accessible. Clean any dirt or grit away from round the plug. Remove the plug and fill up to the bottom of the threads. This gives the correct level.

Front Shock Absorbers.—Remove the filler plug, taking care that dirt does not enter the casing, and check that the fluid level is maintained to within ⅝ in. of the plug opening. If the fluid level appears to be low, examine the shock-absorber casing for signs of leakage. Use only recommended shock-absorber fluid for topping up as indicated on the lubrication chart. On later shock absorbers having a deep filler-plug well, check that the fluid is level with the bottom of the opening. It is impossible to overfill this latest type of shock absorber.

Clutch Pedal.—With the oil-gun lubricate the nipple at the base of the pedal lever.

Propeller-shaft Splined End.—Oil the nipple on the sliding yoke at the gearbox end of the propeller shaft.

Rear Axle.—Check the level and replenish if necessary. The correct oil should be used and injected into the axle casing from the left-hand side, using the special adapter on the oil-gun.

Before removing the filler plug carefully clean the surrounding surfaces, as grit allowed to enter the casing will cause wear. Remove the plug and then place the end of the adapter into the oil-hole and push the barrel of the gun.

The plug also serves as an oil-level indicator. Therefore do not replace the plug at once, but allow time for the superfluous oil to run out if too much lubricant has been injected.

This is most important, because if the rear axle is overfilled the lubricant may leak through on to the brake linings and render them ineffective. Wipe the excess oil from the casing.

Steering Column.—Lubricate the felt washer at the top of the steering column by adding a few drops of light machine oil through the oil-hole in the steering-wheel hub close to the column.

Brakes.—Examine the brakes and adjust if necessary. Oil the brake balance lever on the rear axles, the handbrake pivot, and the brake-pedal pivot nipple.

Battery.—Ascertain the state of the charge of the 12-volt battery by taking hydrometer readings. The specific gravity readings should be:

Fully charged	1,280 to 1,300
Half-charged	approx. 1,210
Discharged	1,150

These figures are correct for an electrolyte temperature of 60° F.

Check that the electrolyte level in the cells is just level with the tops of the separators. If necessary add a few drops of distilled water. Never use tap water as it contains impurities detrimental to the battery.

Never leave the battery in a discharged condition. If the car is to be out of use for any length of time, have the battery charged about once a fortnight.

Brake Supply Tank.—Inspect and refill to the correct level. Use only the recommended fluid.

Every 3,000 Miles Maintenance

Sparking Plugs.—Remove the plugs, dismantle and clean off all carbon deposit from the electrodes, insulators, and plug threads with a stiff brush dipped in paraffin. Alternatively, the non-divisible types of plugs may be cleaned in a special machine.

Clean and dress the plug points and reset to the correct gap of ·017–·018 in. by moving the outside electrode.

Before replacing the plug check that the copper washer is in a sound condition. Never overtighten a plug in the cylinder head, but ensure that a good joint is made between the plug body, the copper washer and the head.

Distributor Cam- and Drive-shaft Bearings.—Lubricate the distributor cam-shaft bearings by withdrawing the moulded rotating arm from the top of the distributor spindle and adding carefully a few drops of thin machine oil round the screw exposed to view. Take care to refit the arm correctly by locating it in its keyway and pushing it on to the shaft as far as it will go.

Distributor Cam.—Apply a trace of clean engine oil to the distributor cam. The contact-breaker arm should be lifted off its spindle for this latter attention. Be careful not to let any grease or dirt reach the contact-breaker points.

Contact-breaker Pivot.—Test for free opening of contact points with finger pressure. If the movement is restricted the breaker spring must be released from the screw at the side of the baseplate and the contact lifted off its pivot. Clean the pivot, lightly oil, and replace.

Distributor Automatic Advance.—Remove the distributor cap and add a few drops of thin machine oil through the hole in the contact-breaker base through which the cam spindle passes. Do not allow any oil to get on to or near the contacts. Check the tightness of the contact-breaker base screws and replace the cap.

Every 5,000 Miles Maintenance

Air Cleaner.—As well as acting as an air-intake silencer and cleaner, by a coupling to the rocker cover it also acts as a fume extractor.

Every 5,000 miles the air cleaner should be removed, cleaned, and " wetted " with fresh oil. To do this slacken the clamping bolt and the hose clip between the cleaner and the rocker cover, lift the air cleaner off the carburettor, and then thoroughly rinse the louvred end in a shallow dish of petrol.

After drying, the metal-gauze mesh should be re-oiled with clean engine oil, allowing the surplus oil to drain off before refitting the cleaner to the carburettor.

Refit the cleaner with the gauze facing forward, and retighten the clamp.

[*Note.*—In countries where dust is constantly experienced it is advisable to attend to the air cleaner more frequently. Certain export models are fitted with an oil-bath-type cleaner.]

Fuel System.—Check the flow of the fuel at the carburettor inlet union and, if necessary, clean the petrol filters in the pump and in the carburettor inlet union, and also clean the jets.

Radiator.—Flush out the cooling system by opening the drain taps. There is one at the bottom of the radiator and another on the right side at the rear of the crankcase. Open the heater water-cock. Water should then be allowed to run through until it comes out clean.

When refilling, and particularly if cold water is used, a few minutes must be allowed for air to escape past the thermostat valve before final topping up is effected.

In winter, when flushing the radiator, take care to preserve the cooling mixture if anti-freeze has been added.

Fan Belt.—The fan belt must be sufficiently tight to prevent slip, yet it should be possible to move the centre of the belt sideways about 1 in.

To make the necessary adjustment slacken the adjustment bolts on the dynamo brackets and raise or lower the dynamo until the desired tension of the belt is obtained. Then securely lock the dynamo in position again.

Speedometer Drive.—Disconnect the cable from the speedometer end and pull the inner member out of the casing. Lubricate by dipping in fairly thick oil and allowing to drain.

To reassemble, thread the oily member back into the casing, and while threading give it a twisting movement, since this will help it to engage easily at the gearbox end. When this engagement is felt the shafting can be pushed right home, so that the top square end stands out from the casing approximately ⅜ in.

Front Road-wheel Hubs.—Remove the front hub grease cap, accessible after removing the wheel disc, and if necessary repack the front hub bearings with grease. It is important that the hubs are not given too much grease, otherwise it will penetrate to the brakes.

Rear Road-wheel Hubs.—These are packed with grease upon assembly and do not require greasing attention.

Gearbox.—Drain when the oil is warm (after a run), and refill to the level of the filler plug with new oil. Capacity 2¼ pints (2·7 U.S. pints, or 1·26 litres).

Rear Axle.—Drain when the oil is warm (after a run) and refill to the level of the filler plug with new oil. Capacity 2¾ pints (3·3 U.S. pints, or 1·54 litres).

Steering Gear.—The steering box should be topped up with oil, using the special adapter on the oil-gun. Take out the hexagon plug on the side of the steering box to inject the oil. Make certain that grit does not enter the casing during the operation, and wipe away any excess oil afterwards.

Rear Shock Absorbers.—Remove the rear shock absorbers to check the fluid level and top up if necessary. Take care dirt does not enter the casing. Top up to within ⅝ in. of the filler-plug face. Use only recommended shock-absorber fluid for topping up.

Decarbonising and Tappet Adjustment.—This attention may not be needed so frequently on cars used for long journeys. As a general guide, a falling off in engine power with " pinking " indicates when decarbonising is overdue. When the car has been used from the new condition it will usually be found that decarbonising is necessary after the first 2,000–3,000 miles, although the engine will continue to pull fairly well over a longer period. After decarbonising, the valve-tappet clearances should be set at ·015 in. for both inlet and exhaust valves when the engine is cold.

Other Items of Maintenance Attention

In addition to the previously explained maintenance items there are some further important factors that must be attended to at the intervals mentioned.

AT 500 AND 2,000 MILES

The engine should be drained and refilled with fresh oil after the first 500 miles running, and again after the next 2,000 miles running.

With a new (or reconditioned) engine, at the same time as these changes are made the cylinder-head nuts should be tested and tightened if necessary.

During the running in and settling down period with a new engine (approximately 1,000 miles), a slight falling off of power sometimes develops; it is then advisable to lightly grind in the valves and reset tappet clearances to ·015 in. On such an occasion there is no need to decarbonise the tops of the pistons.

Gearbox and Rear Axle.—Also after the first 500 miles drain and refill the gearbox and rear axle on new vehicles.

Always drain the oil after a run, since it will then flow more easily.

AT EVERY 10,000 MILES

Propeller Shafts and Universal Joints.—Lubricate the universal joints. Move the car to expose the two nipples.

Also test the flange bolts, and tighten if these have worked loose; the nuts are secured with tab washers.

Ignition Timing.—Check the setting and adjust if necessary.

Clutch-operating Shaft.—Oil the two nipples—one each side of the clutch housing—sparingly, as any excess may find its way on to the clutch linings.

Sparking Plugs.—Renew the sparking plugs.

Dynamo Bearings.—Unscrew the wick-type lubricator with slotted end, and if the wick is dry refill the cup with petroleum jelly or H.M.P. grease.

Contact-breaker Points.—Clean the contact-breaker points. Cleaning of the contacts is made easier if the contact-breaker lever carrying the moving contact is removed. To do this slacken the nuts on the terminal post and lift off the spring, which is slotted to facilitate this. Before replacing smear the pivot on which the contact breaker works with clean engine oil.

Check the contact-breaker setting and reset if necessary. The correct gap is ·010–·012 in.

Dynamo and Starter Commutators.—Clean and check freedom of brushes in holders.

Track Adjustment.—Check front-wheel alignment: $\frac{1}{16}$–$\frac{1}{8}$ in. “toe-in.”

Steering Gearbox.—Check for wear.

Clutch-pedal Clearance.—Check, and adjust if necessary.

Oil Sump.—Remove and clean sump and oil-pump strainer gauze.

Front and Rear Hub Bearings.—Check for signs of wear.

External Oil Filter.—Remove old filter and replace with new unit. Scratch the mileage of car on filter casing when renewing filter. Capacity of filter is 1 pint.

In general, all bolts and nuts should be checked, notably on the road-spring clips, cylinder head, wheel nuts, and body anchorage nuts.

(2) Overhaul and Repair of Vehicles

In the preceding section, which concerns the maintenance of a typical motor-car from its new condition, most of the work done has been in connection with the lubrication and adjustments of the various chassis components in order to keep the vehicle in good running order as long as possible before it becomes necessary to undertake actual repairs or replacements that have occurred as a result of normal wear. This branch of the motor-garage work is an important one, necessitating the installation of special tools and equipment and the services of skilled operators.

It is here proposed to give a general outline of some of the more usual items of overhaul and repair, but without discussing the methods, tools, or equipment employed; these methods are dealt with in fuller detail in the various sections of the four volumes forming this work.

In connection with the periods at which the overhaul of any of the components of a motor vehicle should be undertaken, it is not possible to give any information that would be applicable to all vehicles, since these periods will be largely dependent upon the manner in which the vehicle has been driven, the adherence or otherwise to the manufacturer's maintenance schedule, the nature of the roads, and the loads carried, etc.

The rate of wear of the working parts of a motor vehicle *will be greatest* when the vehicle is badly driven, namely with violent acceleration and braking, consistently high maximum speeds, fast cornering, and misuse of the gearbox. Similarly, if the lubrication and adjustments necessary at the stated mileage intervals have not been attended to regularly more wear will occur. Again, if the vehicle is used on hilly roads or mostly in towns, where frequent starts and stops are required, it will have a shorter life before overhaul becomes necessary.

Another important factor is that of the vehicle's loading, since regular overloading will result in an appreciable increase in the wear of the components concerned.

It is therefore possible for vehicles of the same date and design to differ considerably in the total mileage periods before general or component overhaul and repair become essential. Thus one particular make of vehicle, e.g. a motor-car, may run for 40,000 miles or more before the wear effects become noticeable, whereas the neglected, badly driven, or overloaded car may need repair attention in just over one-half the distance.

It may here be added that the regular decarbonising of the engine and regrinding of the valves have been considered as maintenance and not overhaul operations.

Typical Instances of Component Wear

Whilst it is not necessary here to give a detailed analysis of all the engine, transmission, steering, springing, control, electrical, and other components that may need complete overhaul, replacement, or repair, a few typical examples are given to illustrate the subject under discussion.

(*a*) *The Engine Unit.*—After prolonged usage the power unit of a motor-vehicle experiences wear in its moving components. Thus the piston rings, piston sliding surfaces, gudgeon pin and small-end bush, big-end connecting-rod and main bearings, camshaft bearings, crankshaft journal, timing gears, valve faces and seatings, valve stems and their guides, tappets and their guides, rocker-arm bearings, etc., are all affected by the wear factor to a greater or lesser extent. Similarly, the barrels of the cylinder block are very prone to wear. Any general overhaul of the engine unit therefore necessitates the examination for undue wear effects in these and other engine components, e.g. the oil pump, ignition unit moving parts, water pump, etc. Excessive wear in an engine necessitating its overhaul at an appreciably shorter mileage period than is normal for the make may be due to inattention to the regular items of maintenance, inadequate lubrication, excessive acceleration and driving the car at high speeds, excessive use of the carburettor choke, starting off from cold without a preliminary warming period, use of unsuitable lubricants, and other contributory factors.

The chief items with which the motor engineer is concerned include those of worn cylinder bores and valve seatings, crankshaft journals, and connecting-rod and crankshaft bearings. His garage equipment should therefore be chosen to cope with the reconditioning of these components.

(*b*) *The Transmission.*—This comprises the clutch unit, gearbox, propeller shaft with its universal joints, and the back axle. After long service wear may occur in the clutch friction members, bearings, and operating mechanism.

The gears in the gearbox may become noisy on account of worn teeth and worn main and layshaft bearings. The gear-operating mechanism, either of the steering column or hand gearbox lever pattern, will show indications of wear in the pins and bearings and striking-gear parts. Oil seals may need renewal. Synchromesh gear components also may require attention.

The propeller shaft universal joints usually have a long life, unless their regular lubrication has been neglected, when wear may occur in the splined joint and the star pins and bearings.

The rear axle unit, with its final drive gears, differential unit, axle half-shafts and bearings, has many possible regions of wear, notably in the gear teeth and bearings, all of which require careful examination. In many cases, however, adjustments provided will take up wear in the bearings.

(*c*) *The Suspension System.*—This is a heavily stressed system, the components being under rapid impact loading under road conditions. The various wearing surfaces, such as the shackle pins and their bushes, the front suspension (independent) with arm bearings, shock absorbers, etc., may need the attention of the mechanic.

(*d*) *The Steering System.*—Usually provision is made for taking up any wear effects in the steering gearbox, but other members such as the steering mechanism and king-pin joints may require reconditioning. The castor camber and king-pin angles, and the front-wheel "toe-in" will need to be checked when a major overhaul is undertaken, whilst the "toe-in" should also be examined at regular intervals as a maintenance item; otherwise heavy steering and excessive tyre wear may result.

(*e*) *The Braking System.*—The brake shoes, brake drums, and all pins and bearings in the braking mechanism from the clutch pedal to the wheel drums, the hydraulic, pneumatic and vacuum braking systems should be checked as explained later in this work.

(*f*) *The Electrical System.*—Complete overhaul of this system involves examination and test of the ignition system (distributor, contact breaker, plugs, and cables with their connections), the battery, dynamo (with cut-out and regulator units), starting motor, and switch, with a complete check also of the electrical components and the whole of the wiring system. The commutators and brushes of the dynamo and motor will probably need servicing at this stage.

(*g*) *Miscellaneous.*—Other miscellaneous items that may require complete overhaul include the radiator, wheels (if damaged), tyres, and the bodywork if damaged or needing repainting.

(3) Road Accidents and Breakdowns

The modern motor garage should be provided with the essential tools and equipment for dealing expeditiously with breakdowns on the road and also road accidents. These may occur at appreciable distances from the garage, so that part of the equipment should consist of means for lifting the front or rear portion of the disabled vehicle or, in some cases of severe accident, the complete vehicle, and towing it back to the garage for repair purposes. A breakdown or salvage lorry fitted with a set of the essential tools and appliances, and a powerful lifting crane mounted on the rear end of the salvage vehicle, are essential. A towing ambulance, towing bars, steering lock, and other salvage gear should also be carried. In the case of breakdowns on the road which do not include damage to any part of the vehicle but are due to failure of one of the units, e.g. the engine, clutch, gearbox, back axle, steering, or brakes, the breakdown car should be supplied with the essential tools for making emergency repairs or for remedying the trouble. In the case of engine or tyre trouble a complete cure may usually be effected on the road or in the owner's garage, thus enabling the vehicle to proceed satisfactorily. In other instances of more serious mechanical breakdown the vehicle will need to be towed to the motor-repair shop, using a breakdown or other towing vehicle.

The nature and amount of the tools and equipment that must be carried by the breakdown cars will, of course, depend upon the more frequent causes of road or private garage breakdowns, and in this connection some valuable information has been collected year by year by the Royal Automobile Club, and the results have been analysed and presented in a convincing and useful manner.

Before proceeding to consider the causes of such breakdowns it should be pointed out that these are to a large extent concerned with the design of the car and its year of manufacture. Thus the introduction of new design features and methods of construction, which takes place progressively, has an important influence upon the nature of the failures that occur on the road, so that one finds the causes and proportions of breakdowns change from year to year.

As there are numerous pre-war vehicles still in service on our roads, it may be of interest to consider first the general types of road failures of such vehicles, taking for our purpose cars of the two-year period before the 1939 war. The results of the R.A.C. analysis are shown on this page.

TABLE 1.—ANALYSIS OF PRE-WAR BREAKDOWNS

	Percentages	
1. *Power unit :*	*1938*	*1939*
(*a*) Ignition	21·2	22·9
(*b*) Carburation	5·1	6·1
2. *Engine :*		
(*a*) Cylinders and pistons	9·9	9·1
(*b*) Valve mechanism, camshaft, layshaft, timing gear	3·0	3·2
(*c*) Valves	1·7	0·8
(*d*) Lubrication	2·0	1·6
(*e*) Cooling system	2·9	3·2
(*f*) Crankshaft	1·2	1·8
(*g*) Not stated	4·4	3·9
(*h*) Starting system	1·0	0·8
3. *Transmission :*		
(*a*) Clutch	6·1	6·2
(*b*) Gearbox	2·7	3·0
(*c*) Couplings, universal joints, and propeller shafts	3·9	2·8
4. *Back-axle unit:*		
(*a*) Axle shafts	15·3	15·9
(*b*) Differential	0·6	0·4
(*c*) Bevels and worms	1·2	1·1
5. *Front axle and steering*	1·5	1·8
6. *Braking system*	0·5	0·3
7. *Road wheels and springing system*	3·1	2·6
8. *Lighting failures*	2·4	3·1
9. *Accidents*	10·3	9·4
	100·0	100·0

The results shown in this table afford some useful information to the motor engineer.

Thus it is seen that by far the *greatest number of road breakdowns*, viz. between 22 and 23 per cent. of the total, was *due to ignition trouble*. Hence the breakdown vehicle should be specially equipped to deal with such troubles; in most instances these can be dealt with satisfactorily on the spot and the vehicle is then able to proceed.

The next important cause of breakdown is that due to *broken axle shafts* (half-axles), viz. between 15 and 16 per cent. This is not altogether surprising, as these shafts are heavily loaded under repeated stress conditions, namely, torsional ones, and finally fracture by fatigue effect. Next in order come the *cylinders and pistons*, which often fail by piston seizure, broken rings or pistons. Between 9 and 10 per cent. of all breakdowns are due to this trouble.

The only other more serious item is that of clutch trouble, which accounts for about 6 per cent. of road failures.

It is of interest to consider the principal units, namely, the engine, transmission, and back axle, etc., collectively in order to ascertain which unit gives the more frequent trouble on the road. The results of an analysis are as follows:

TABLE 2.—COLLECTIVE RESULTS OF BREAKDOWNS CAUSES

	Percentages	
	1938	*1939*
1. *Power unit:*		
(*a*) Engine	26·1	24·4
(*b*) Ignition	21·2	22·9
(*c*) Carburation	5·1	6·1
2. *Transmission* (total)	12·7	12·0
3. *Back axle* (total)	17·1	17·4
4. *Front axle and steering*	1·5	1·8
5. *Other causes*	16·3	15·4
	100·0	100·0

It will be observed from this general analysis that *the power unit* accounts for more than *one-half the number of breakdowns*, followed by the *back axle* with just over 17 per cent., and the transmission with between 12 and 13 per cent.

Comparison Between Pre-war and Post-war Cars

It is of particular interest to those concerned with breakdown troubles to know how the causes and percentages of pre-war and post-war failures compare. For this purpose two analyses, prepared by the R.A.C., have been chosen, namely, those for the years 1937 and 1947, and the results are given in Table 3.

TABLE 3.—ANALYSIS OF PRE-WAR AND POST-WAR CARS

	Percentage	
1. *Power unit:*	*1937*	*1947*
(*a*) Ignition	20·20	14.61
(*b*) Carburation	7·58	6·428
2. *Engine:*		
(*a*) Cylinders and pistons	9·50	11·43
(*b*) Valve mechanism	0·88	2·24
(*c*) Valves	1·06	1·25
(*d*) Lubrication	1·66	1·24
(*e*) Water circulation	6·00	4·11
(*f*) Crankshaft	0·74	1·21
(*g*) Engine (not stated)	4·58	5·03
(*h*) Starting	1·26	1·26
(*i*) Bearings	(not shown)	2·50
3. *Transmission and brakes:*		
(*a*) Clutch	6·80	6·68
(*b*) Gearbox	3·40	3·60
(*c*) Universal joints and propeller shafts	1·98	3·87
(*d*) Brakes	0·71	1·58
4. *Back axle:*		
(*a*) Axle shafts	15·30	16·53
(*b*) Differentials	0·32	0·84
(*c*) Bevels and worms	1·24	0·77
5. *Front axle and steering*	2·08	5·57
6. *Road wheels and suspensions*	3·87	1·15
7. *Lighting*	1·47	2·68
8. *Accidents*	9·37	4·79
9. *Run out of petrol*	(not shown)	0·64
	100·00	100·00

A brief survey of the results given in Table 3 indicates that there is appreciably less trouble on account of the ignition system in the post-war car, but only a slight reduction in the carburation system troubles.

The *later model engines* give rather *more trouble* in regard to their cylinders, pistons, valve mechanism, and crankshafts than the pre-war model.

In regard to the *transmission*, there is an appreciable increase in the trouble due to the propeller-shaft unit, the percentage increasing from 1·98 in 1937 to 3·87 in 1947.

The troubles due to the *braking system* have all doubled in the post-war car, whereas there is less trouble with modern bevel and worm gears in the back axle. With the introduction of *independent front-wheel springing systems* with their more involved mechanisms and having regard to their relative newness, it is not altogether surprising to find that more trouble has been experienced with them as compared with the pre-war cars. Thus, 5·57 per cent. of the failures in 1947 cars were due to the front axle and steering system as compared with 2·08 per cent. in 1937. A significant fact about the comparative results is that with the exception of the ignition and carburation failures, there was a greater percentage of these failures in most of the other components or units in 1947, as the following results show:

TABLE 4.—COLLECTIVE RESULTS OF BREAKDOWNS CAUSES

	Percentage	
	1937	*1947*
1. *Power unit:*		
(*a*) Engine	25·68	30·27
(*b*) Ignition	20·20	14·61
(*c*) Carburation	7·58	6·42
2. *Transmission*	12·89	15·73
3. *Back axle*	16·86	18·14
4. *Front axle*	2·08	5·37
5. *Road wheels and suspension*	3·87	1·15
6. *Other causes*	10·84	8·11
	100·00	100·00

It may be mentioned that in addition to new designs of front axle and steering systems contributing to the increase in the post-war failures on the road, the increase in the percentage failures in the engine, transmission, back-axle and front-axle systems is probably due to the higher performances of the cars in question.

A More Recent Breakdown Analysis

As a final example of the types of trouble due to breakdown on the roads with which the motor engineer is concerned, we have taken the results of an R.A.C. analysis for the latest date prior to the publication of this edition. The results are shown in Table 5, and it will be noted that to actual totals of failures are given in the next column the percentages.

It is significant that the most frequent causes of breakdowns in the case of cars on the road—and these necessarily contain an appreciable number of pre-war cars—are the cylinders and pistons, ignition system, and axle shafts. The clutch is also a fairly constant source of trouble, and always has been from pre-war times.

In concluding these analyses it is believed that the motor engineer in charge of the repair shops or garage will find a good deal of valuable information concerning the types of trouble he is liable to be called upon to deal with in connection with actual breakdowns on the road. He will thus be in a position to select his equipment and arrange for the most expeditious remedies for these troubles.

TABLE 5.—RECENT BREAKDOWNS ANALYSIS

	Total	*Percentages*
1. *Power unit:*		
(*a*) Ignition	1,312	19·09
(*b*) Carburation	610	8·87

	Total	Percentages
2. *Engine:*		
(*a*) Cylinders and pistons	646	9·40
(*b*) Valve mechanism	90	1·31
(*c*) Valves	55	0·80
(*d*) Lubrication	112	1·63
(*e*) Water circulation	229	3·33
(*f*) Crankshaft	79	1·15
(*g*) Engine (not stated)	330	4·80
(*h*) Starting	100	1·45
(*i*) Bearings	178	2·59
3. *Transmission and brakes:*		
(*a*) Clutch	377	5·48
(*b*) Gearbox	230	3·35
(*c*) Universal joints and propeller shafts	186	2·71
(*d*) Brakes	72	1·05
4. *Back axle:*		
(*a*) Axle shafts	1,122	16·32
(*b*) Differentials	61	0·89
(*c*) Bevels and worms	81	1·18
5. *Front axle and steering*	228	3·32
6. *Road wheels and suspensions*	252	3·66
7. *Lighting*	130	1·89
8. *Accidents*	314	4·57
9. *Run out of petrol*	80	1·16
	6,874	100·00

CHAPTER 2

GARAGE SMALL TOOLS, MACHINES, AND GAUGES

Tools for the Small Garage

The question of the best tools to provide for the small garage-workshop is an important one, for it is on the selection of his tools that the worker depends for the quality of his work and, what is more important, on the ease and rapidity with which he executes this.

There is a certain minimum number of tools essential to good and expeditious work—certain tools which the worker must have if he is to tackle any ordinary motor-car job satisfactorily.

It is good advice to purchase the highest-quality tools that can be afforded; those with the maker's name are the best.

The material should be well hardened and tempered where the cutting or gripping edges occur; it is important that each cutting tool should have ample material for grinding down or sharpening purposes; this ensures a long life.

There should be no appreciable slack in the joints of component tools, such as pliers, cutters, shifting spanners, and wrenches.

Nothing is more annoying than to find that a shifting spanner, which has been " set " to a given nut, is constantly altering its jaw dimensions, on account of slackness in the nut.

Tools should be well finished, and rust-proofed as far as possible. Nickel-plated or " blued " steel tools are preferable for this reason. *Case-hardened tools* should be avoided; once the casing is worn through the life of the tool is not a long one; the best tools are those in which the jaws or cutting edges are hardened throughout and tempered.

It is also better to purchase a tool for a specific purpose, rather than a *multum in parvo* combination claimed to combine the functions of a number of common tools; the latter usually fail to operate satisfactorily, are often badly made and are most awkward to manipulate; an instance of this is the so-called screw-driver on one end of a pair of pliers. Of course, there are certain tools—for example, "quick-grips," gas-pliers, cone-pliers, and ordinary flat pliers with cutting edges—which are very satisfactory.

Reverting to the subject of essential tools for a small motor workshop, it may be said that the contents of one or two makes of motor tool-roll form a useful starting-point from which to acquire a good set of tools.

The inferior types of tool-roll and those often supplied with new cars under the heading of " Free kit of tools " are usually limited in their applications.

Fig. 2 illustrates an inexpensive but well-selected tool-roll. A more elaborate tool-rool with eighteen tools of various kinds is supplied by the same firm; the additional tools include gas-pliers, adjustable jaw wrench, hand vice, tool handle, set of pliers, punches, or drifts.

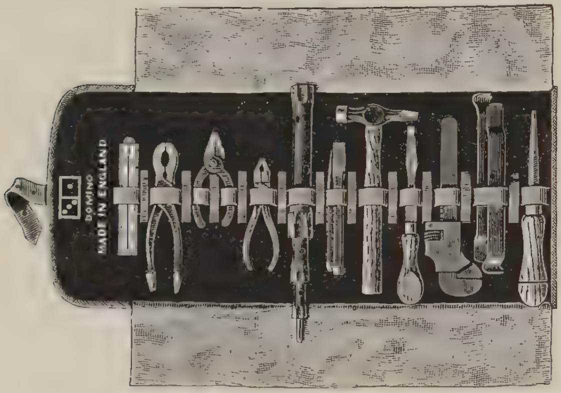


Fig. 2.—A Well-equipped Tool-roll.

The following is a list of recommended tools, intended to represent the minimum requirements of the small garage worker: Engineer's 4-in. bench vice; hand-drilling machine of the two-speed-gear type; bench grinder; set of small drills from $\frac{1}{8}$ to $\frac{3}{8}$ in., advancing in size by $\frac{1}{16}$ in.; set of Whitworth taps, stocks, and dies, from $\frac{3}{16}$ in. to $\frac{3}{8}$ in. in $\frac{1}{16}$-in. sizes (the quick-cut dies are useful in this respect); set of British Standard Fine Thread (B.S.F.) taps and dies; set spanners, double-ended, from $\frac{3}{16}$ in. to $\frac{1}{2}$ in.; box spanners in corresponding sizes, double-ended; set of pliers (flat-nosed, round-nosed, cone, cutting, and gas); set of adjustable spanners (including small, medium, and large screw adjustable spanner, and Clyburn types), combination pliers (with side cutters), cold chisels (large and small, flat and cross-cut); screw-drivers (instrument, medium, and large sizes); hammers (riveting, copper or hide, $\frac{3}{4}$ lb. and heavy or $1\frac{1}{2}$ lb.); centre punch; copper drift, pin punches (2 or 3 sizes); set of files (about one dozen, round, half-round, flat, square, three-cornered, ward, in fine, bastard and coarse cuts) with handles; set of tyre spanners; magneto file (the Footprint motorist's knife contains magneto file, reamer, contact-point gauge and knife blade); set of metal scrapers (flat, three-square and half-round); dividers; callipers (inside and outside); feeler gauge set (in thousandths); split-pin extractor; pair of tinman's snips; tap wrenches; reamers ($\frac{1}{8}$ to $\frac{3}{8}$ in.), soldering irons (large and small); hacksaw (adjustable type for 10-in. and 12-in. blades); valve lifters (two or three different types); hub-cap spanners; punches for leather, card, or fibre sheet. It is, of course, possible to elaborate this list, but we believe that the reader will find the essential tools included. Special tools are not mentioned, as these are either made to requirement or form part of the motor-car special appliances provided by the makers; for example, valve lifters, hub spanners, and sparking-plug spanners.

Dump Boxes

It is only possible to enumerate those items which have personally been found most useful or essential, but the motor-owner and engineer will in the course of time learn to keep his own items which experience indicates necessary. No real hard-and-fast rules can be laid down in this case, but most enthusiastic owners, chauffeurs, and others will accumulate various oddments of occasional or frequent utility in their garage-workshop. In this respect we have always found it an excellent plan to have a few " dump " boxes, one for large pieces of " salvage," " dump," and all sorts of odd metal articles one comes across; another for larger bolts, nuts, screws, washers, etc., and another for small items; these are collected from the bench and other sources at intervals, and once in a while the " dump " boxes are sorted out and the contents returned to their appropriate bins, compartments, or boxes.

It is a good plan to keep one " dump " box for electrical items, such as terminals, cable fittings, switches, contacts, staples, and similar items.

The " dump " box is usually the first and last resource of the garage worker when he requires miscellaneous motor items for special purposes.

Some Important Small Tools

Whilst it is not proposed to describe the ordinary workshop small tools with which it must be assumed most mechanics are fully conversant, a few important tools of practical utility to the motor mechanic will here be mentioned. These tools enable jobs to be tackled quickly and efficiently, and mostly they have advantages over the other more common tools. An improvement over the ordinary pipe wrench, the Stillson design is usable on any round or octagonal components or nuts. It has a wide range of adjustment and a long lever handle. The fixed hardened and serrated jaw on the wrench is inclined to the handle, whilst the movable jaw is hinged so that it can accommodate itself to different diameters, adjustment being made by a knurled cylindrical nut member arranged within the gap of the adjustable jaw. Normally, this type of wrench would not be used on motor-vehicle nuts, since the serrations of the jaws tend to damage the faces of the nut, but in cases where the nut is difficult to unscrew this type of wrench will usually overcome the trouble.

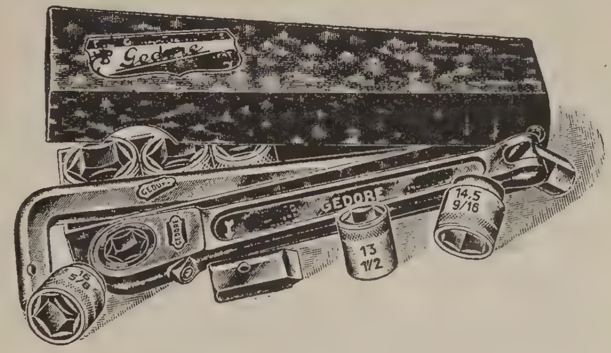


Fig. 3.—A Useful Box-spanner Set.

A useful box spanner set, and one that should be found in every small and large garage, is shown in Fig. 3. It consists of a hexagonal shank bent over at one end; the various sizes of box spanner ends fit over this latter part and are held in position by means of a spring-loaded ball. There are several such box spanner sets on the market, covering all motor-vehicle nut requirements. The one illustrated includes six box spanner ends from $\frac{1}{4}$-in. to $\frac{5}{8}$-in. Whitworth. For storage purposes all six ends can be slid over the longer arm of the shank, a spring-loaded ball holding them in place. With the set illustrated a ratchet lever to slip over a hexagonal piece, and a universally-jointed hexagonal unit to fit into the standard hexagonal hole in each box spanner end, are supplied. There is also a short hexagonal unit having a stout screw-driver blade.

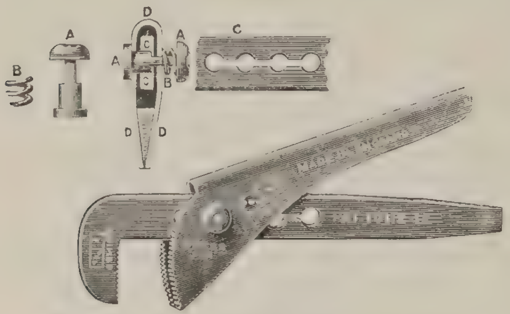


Fig. 4.—A Handy Adjustable Pipe Spanner. Showing details (above).

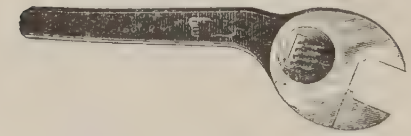


Fig. 5.—"Clyburn" Spanner.

The press-pin wrench shown in Fig. 4 is a useful tool for gripping irregular objects, pipes, rods, and the like. By merely pressing the button shown the movable jaw can be slid along the slot in the fixed jaw handle, so as to vary the jaw opening over a very wide range. It is made in sizes ranging from $5\frac{3}{4}$ in. to 14 in., is well made, hardened, and strongly constructed. This wrench is also known as an "adjustable pipe-tongs"; it can be used for refractory nuts which have had their corners rounded by the use of unsuitable spanners.

A very useful form of spanner is the "Clyburn" adjustable type shown in Fig. 5. This possesses all the advantages of the fixed or set spanner, and in addition enables a range of nut sizes to be dealt with; in effect, it dispenses with a number of set spanners. It is strongly made, and has a jaw opening from $\frac{1}{4}$ in. to 1 in.; the length is 6 in.

The cone-pliers shown in Fig. 6 will be found useful for holding nuts, washers, or pin heads of small width, and for the cone bearings of cycles. The smaller jaws D are for gripping small rods or objects and the larger jaws C for larger diameters. The pliers have a wire-cutting edge at A, and one of the handles has a screw-driver point.

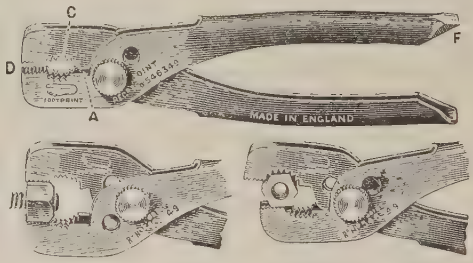


Fig. 6.—Adjustable Cone-pliers.

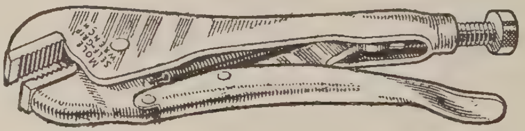


Fig. 7.—The Mole Self-grip Tool.

Another useful design of modern wrench, which is also a multi-purpose tool, is the Mole self-grip tool illustrated in Fig. 7. It has a pair of jaws made with hardened serrated steel grips, the jaws being parallel. The wrench can be used in the manner of a spanner on hexagon or round work, and it will lock on to the work by virtue of the adjustable screw shown on the right-hand side. Work of small dimensions can be held in this tool as in a vice, whilst the tool can also be used as a spanner, wrench for various sections of work, or as pliers.

A Shock-action Tool

Fig. 8 shows a useful tool of original conception that has many potential uses in the motor garage and workshop. Known as the He-Man tool, it is a combined wrench and screw-driver incorporating a shock-action device. The action of the tool is illustrated by reference to Fig. 9.

The bit-holder A takes either a screw-driver bit, as shown, or an adapter for standard-type socket wrenches. It is provided with hardened dogs C. The handle J is free to revolve, but the flywheel E is fixed to the main tube D, on which there are hardened dogs F. An internal spring pushes out the helix shaft B as soon as it is released by turning the locking ring K.

If the direction changer G is moved to the " unscrew " end of the slot, as shown by the arrows, and the bit is inserted into the head of a screw which it is desired to remove, then, when the handle is pushed towards the screw, the flywheel will spin round at an increasing speed until the dogs F engage with the dogs C. *At precisely the same moment* the screw receives an end-wise shock which temporarily jars it loose; the screw-driver bit is held firmly in the screw-head slot, and it is given a violent twist, due to the momentum of the spinning flywheel. The combined shock action, although it lasts only for a fraction of a second, is so timed and is so violent in operation that any screw or nut of normal size is usually bound to turn, however rusty or seized it may be.

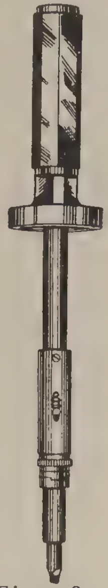


Fig. 8.—Shock-action Tool.

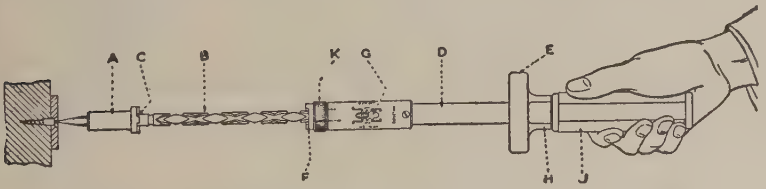


Fig. 9.—Illustrating the Action of Tool shown in Fig. 8.

When the screw is thus loosened, the direction changer is flicked to the ratchet unscrew position at the other end of the slot, and the flywheel is held by inserting the thumb into one of the flutes H on the flywheel boss. The tool then operates as a ratchet screw-driver and spins the screw out.

Assembling and final tightening operations are carried out by working in the opposite direction.

Socket Wrenches

One of the most useful tools of the wrench class for motor-vehicle purposes is the socket wrench, a typical example of which, namely the Churchill model, is illustrated in Fig. 10. It consists of a socket attachment with double-hexagon hole on one side and square hole on the other. The operating handle is similar to that of a carpenter's brace and has a squared end for engaging the socket; a spring-loaded ball holds the latter firmly in position on the squared end. Instead of making the socket with the usual box-spanner hexagon hole, it has a 12-sided hole, or double hexagon, so that it can be fitted to nuts in awkward places at 30° instead of the usual 60° angular intervals.

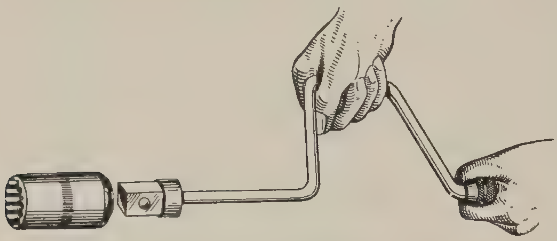


Fig. 10.—Churchill Socket Wrench.

The wrench in question is made of chrome-vanadium steel, and is therefore very strong and at the same time light to handle.

Various accessories are available for extending the uses of these wrenches. Thus the squared end of the handle unit is provided with a universal joint or coupler. Extension bars and a ratchet handle are also supplied.

Instead of the carpenter's brace type of operating device, the sockets can be fitted on to T-handle fixtures so that a more uniform torque is possible.

Stud Insertion and Removal Tools

The removal and insertion of studs on cylinder heads and crankcases can be effected expeditiously with the aid of home-made or proprietary makes of stud tools.

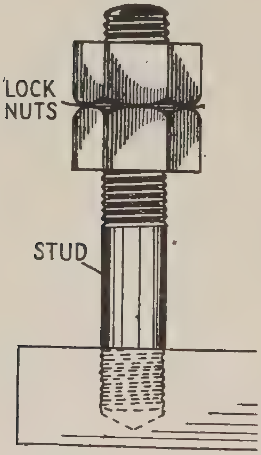


Fig. 11.—Stud Insertion and Removal.

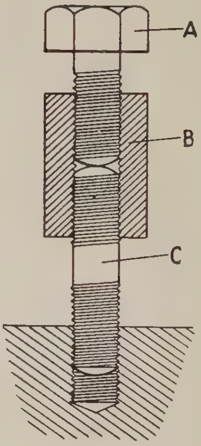


Fig. 12.—Stud-box Tool.

The simplest method (Fig. 11) is to use a pair of hexagon nuts on the upper thread of the stud. One nut is held in the jaws of a set spanner and the other nut is screwed up as tightly as possible against it. In this way the nuts are locked solid one to the other by the process of jamming the threads of the nuts against those of the stud.

To insert a stud the set spanner is used on the upper nut, and when the stud is in its final position the lower nut is unlocked with a second spanner.

To remove a stud the lower nut is used, and is turned in the stud unscrewing direction with the set spanner.

An improvement upon the locking-nut method is the *stud-box* one (Fig. 12). The stud box consists of a relatively long hexagonal nut B and a bolt member A which can be screwed into B. In use the nut member B is screwed on to one end of the stud C for a distance of about one to two diameters, as shown in Fig. 12. Then the bolt member A is screwed down hard on to the top of the stud, where it locks the latter to the hexagon nut member B. The set spanner is then used on B to screw the stud in either direction.

Each of the methods illustrated in Figs. 11 and 12 necessitates screwing the (nut and bolt) members on to the stud, an operation which takes up a certain amount of time. Again, after the stud is inserted the locking member must again be unscrewed or unlocked. In order to speed up the insertion and removal of studs special stud tools have been devised, and are now used in the larger garage-workshops. Typical examples of stud tools are illustrated in Figs. 13, 14, and 15.

Fig. 13 shows a stud-driving tool which is equally suited to the insertion or removal of studs. It is of the double-ended pattern to cater for the insertion and removal of studs. The end members are mounted on to the centre shank by pinned joints, and they have holes of suitable sizes for passing over the studs. The central shank member is provided with hardened serrated ends which enter the stud-holes in the end members; being of curved shape, the toothed portion gives a wedging action when the shank is used in the manner of a spanner. The harder the shank is pulled the tighter it grips the plain portion of the stud. The opposite end of the rool is employed for unscrewing the stud. The tool is available in the $\frac{5}{8}$-in. and 1-in. diameter hole sizes, but each size covers a wide range of stud diameters up to the hole diameter size mentioned.

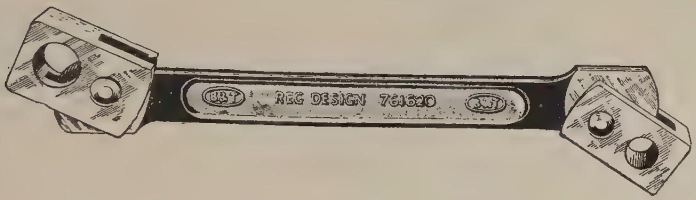


Fig. 13.—The Boneham & Turner Stud Tool.

Fig. 14 illustrates another design of stud tool that is based on the same serrated grip or wedging principle. It has the advantage over the type shown in Fig. 13 of operating above the top of the stud, that is to say, the operating handle is arranged well above the stud, so that when used for cylinder-block studs the operator's hands are clear of the other studs.

Another design of stud tool, shown in Fig. 15, uses a practically identical method, but instead of having a tubular body portion it is made quite short, and has a hexagonal hole above into which a hexagon bar having a bent portion to form the handle is inserted. The tool is therefore very compact in design.

It will be observed that the same method, namely, the use of a serrated member wedging tightly against the stud, is employed in each of the three stud tools just described. If the stud is difficult to insert or remove, the teeth of the stud tool are liable to leave sharp impressions on it, and these have a weakening action on the metal.

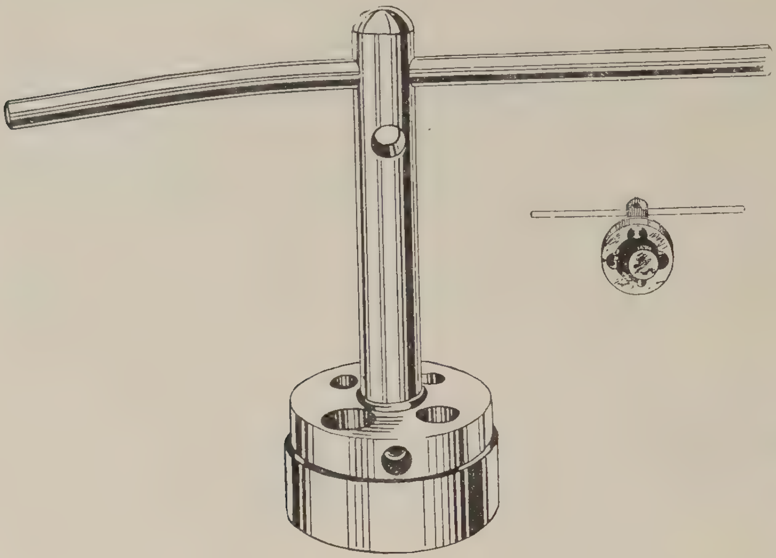


Fig. 14.—Bell-type Stud Extractor.

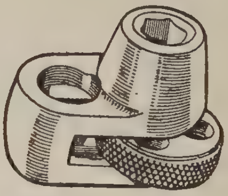


Fig. 15.—A Compact Stud Tool.

It should here be pointed out that the stud tools described must only be used on the plain portions of the studs and not on the threaded parts.

Removal of Broken Studs

It occasionally happens that when nuts are screwed down too tightly or the studs themselves are damaged or weakened, the studs break off either above or below the machined face of the metal, e.g. the upper face of the cylinder block. The broken portion of the stud in either case must therefore be removed without damaging the thread in the stud hole.

(1) *Stud Broken off Above Surface.*—The stud can be removed in most cases by using a wrench of the adjustable pattern but having serrated jaws, such as the type illustrated in Fig. 4 on page 28. If the stud is very tight in its hole, a parallel pair of flats should be filed on the exposed stem portion and the stud then unscrewed with a well-fitting spanner.

In an emergency the exposed portion can often be unscrewed by using a set spanner having its width of jaws slightly larger than the diameter of the stud, and a piece of ordinary round or rat-tail file as shown in Fig. 16. When the spanner is moved in the correct direction for unscrewing the stud the piece of file becomes wedged firmly between the stud and spanner jaw, and this wedging action increases the more the spanner is pulled, so that the stud is gripped firmly and can be unscrewed. It should also be pointed out that the patent stud-removal tools mentioned earlier in this chapter can generally be used for studs broken off well above the surface.

(2) *Stud Broken off Below Surface.*—In the absence of any special tools for the purpose, the usual method of removing the broken portion of the stud is to drill a hole of suitable size down the stud and then tap into this hole the tang of a file, using the file itself to unscrew the stud, as shown in Fig. 17. It is a good plan to inject paraffin or penetrating oil into the hole above the broken stud and to tap the end of the file with a few light hammer blows before attempting to unscrew the stud; this will facilitate the removal of the broken portion.

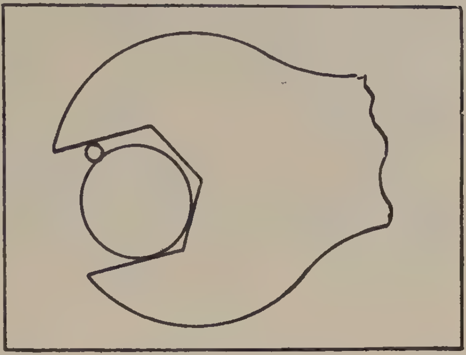


Fig. 16.—Removing Stud with a Set Spanner and Piece of Round File.

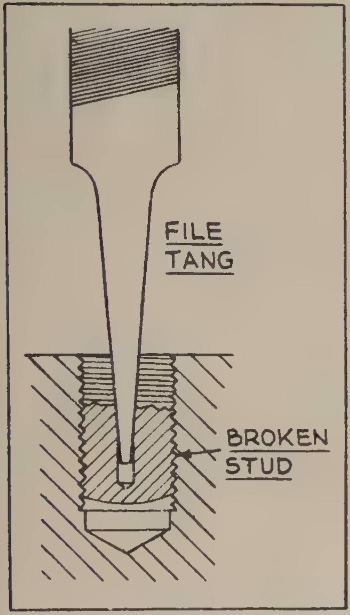


Fig. 17.—Method of Removing Stud broken below Surface.

The method described, if carried out with care, will not result in any injury to the threads of the stud hole.

If, however, the stud end is rusted in or otherwise is too tight, so that it will not yield when the file method is employed, it will be necessary to drill a tapping size hole centrally down the stud and then re-tap the thread in the hole, using the taper, middle, and plug screw taps in the order mentioned.

Special stud-removal tools now on the market are based upon the same principle as that described previously, namely, drilling a hole down the broken stud and using an unscrewing tool. The latter usually takes the form of a tapered tap having a quick-pitch left-hand screw thread which becomes firmly wedged in the hole, and as the left-hand screwing action is then continued, the stud will be moved in the left-hand or unscrewing direction.

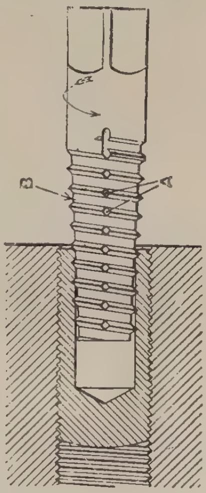


Fig. 18.—A Useful Tool for Removal of Studs broken below the Surface.

Fig. 18 shows a typical stud-removal tool of this class. It has a tapered portion with a coarse-pitch thread of special shape, i.e. thread angle of 90° and fluted as shown at A. A comparatively wide land B is provided between the threads, and it is the resistance of this land in the stud-hole which enables the gripping action between the tool and hole to be achieved. In this way the strain on the extractor thread is relieved to an appreciable extent, and there is less risk of stripping the thread. It may be added that in common with other stud-removal tools the one shown in Fig. 18 is made of tool steel suitably hardened and tempered. One other method of removing broken studs that is here worthy of mention consists in *spot or resistance welding* a steel rod of smaller diameter than that of the root diameter of the stud to the end of the broken stud, care being taken to prevent the rod from becoming welded to the parent metal of the stud-hole by a suitable (asbestos or fire-clay) shroud. The welded-on rod can then be used for unscrewing the broken stud.

Safety Torque Wrenches

In order to avoid the stripping of threads on studs and bolts, or the over-tightening of nuts on automobile components, a new type of safety wrench has been introduced. With its aid the turning effort, or torque, that is applied to each nut of a given size can be regulated to the correct amount and all similar nuts can be tightened up to exactly the same degree, without any risk of over-tightening.

There are several such safety torque wrenches available, of which typical examples are the Sturtevant " Sensory," " Handease," " King Dick," " Apkoway," etc.

The first pattern is illustrated in Fig. 19. It consists of the usual hexagon-type box spanner (on the left) and the operating wrench handle (on the right). It has a graduated sector scale, marked in pounds-feet torque values, on either side of the central zero up to 100 lb./ft. The correct torque value for the particular nut is set on this scale, and when the nut is tightened up the spanner " slips " if a greater effort is exerted, so that only the correct maximum torque is applied. Further, when this torque value is reached, not only is a loud " click " heard, but a strong " kick " or impulse warns the operator of the fact. Thus, such a wrench can be used in the dark or by a blind or deaf person with the assurance that the correct amount of tightening effort has been applied.

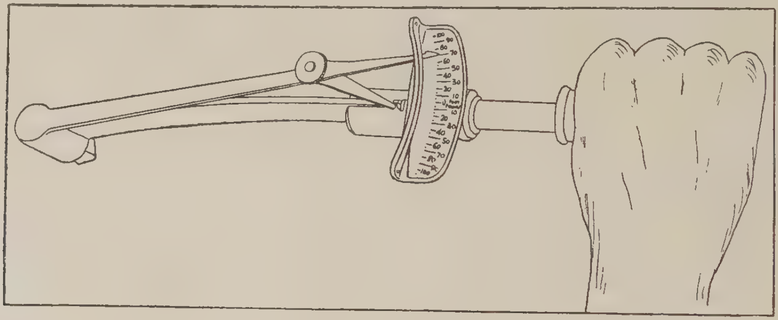


Fig. 19.—The Sturtevant Safety Torque Wrench.

The "Handease"[1] automatic torque wrench has a micrometer-type handle which can be preset to the required torque value. In operation, when this limit is reached a toggle lever brakes with a smooth movement, giving a clear physical indication and a high degree of accuracy. It is claimed that owing to the smoothness of the brake all risk of jerking and consequent overtightening is avoided. Once set, the wrench will brake at the same tension each time, so that the preset torque value is never exceeded. A square drive with spring-loaded friction ball is incorporated for quick and positive socket attachment. The usual hexagon or divided hexagon box-spanner type sockets having square holes at one end are used with this torque wrench.

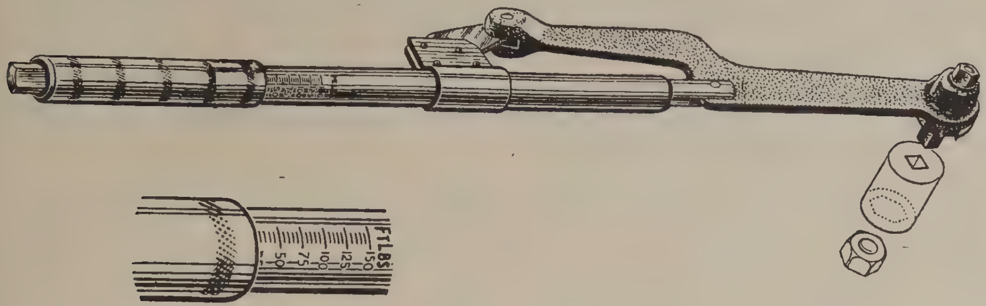


Fig. 20.—Churchill "Handease" Torque Wrench.

The Abingdon "King Dick" torque wrench (Fig. 21) has an adjustable preset scale on the handle for a range of 20–100 lb./ft. When this preset value is reached the wrench slips over the nut, thus indicating to the operator that the given torque value has been attained. The wrench has a ½-in. square-drive ratchet mechanism to fit any ½-in. drive socket.

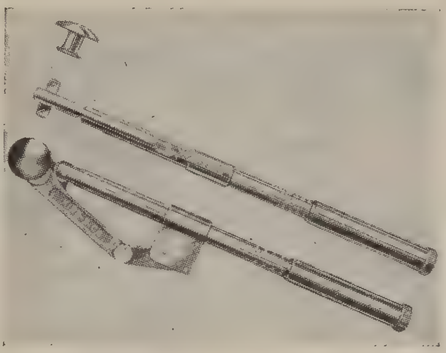


Fig. 21.—The Abingdon "King Dick" Torque Wrench.

The "Apkoway" torque wrench is hydraulically preset by means of a knurled cap until a zero mark on the cap registers with the stud size or pressure markings required on the barrel. Immediately the required pressure has been reached the wrench slips round the socket, so that no further turning effort can be applied to the nut or bolt.

Torque-wrench Readings

The safe value of the torque that can be applied on any nut when it is to be tightened on its thread depends upon the following factors, namely:

[1] H. V. Churchill, Ltd., London, S.E.11.

(1) *The metal* of which the nut and also the bolt is made. The higher the tensile strength of the matter the greater will be the safe torque that can be applied.

(2) *The Pitch of the Screw Thread.*—This determines the root diameter, and the latter governs the torsional strength of the screw, whilst the crest diameter decides the strength of the nut. The safe torque is greater for studs or bolts of finer pitches than for those of coarser pitches.

The actual value of the safe torque for any bolt or nut can be calculated, or it may be found experimentally.

It is unfortunate that only one or two British motor-vehicle manufacturers issue information concerning the correct torque values for the various nuts, setscrews, studs, or bolts used on the chassis components. In the case of American mass-production cars it is the rule to give tables of torque wrench settings in the service manuals.

Some useful information, however, has been given by Messrs. V. L. Churchill & Co., Ltd., for various British cars, and this is reproduced in Table 6.

As an example of the modern car torque wrench readings, the example of the Vanguard is reproduced in Table 7 by courtesy of the Standard Motor Co., Ltd., Coventry.

Nut-splitting Tool

Fig. 22 shows a powerful tool for splitting stubborn nuts which will not turn in the usual manner. It is known as the "Porter Hypowa" nut splitter. In connection with its use for splitting nuts it can be so manipulated that the bolt is not damaged. Another useful tool is the "New Easy" bolt clipper for cutting bolts and rivets; the jaws of this tool can be adjusted accurately (Fig. 23). The last two tools are employed for brake repairs and general chassis work.

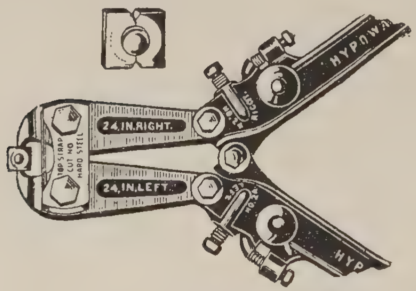

HYPOWA
24 IN. RIGHT.
24 IN. LEFT.
HYP

Fig. 22.—A Powerful Pair of Nut-splitting Pliers.

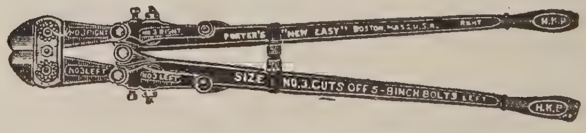

PORTER'S "NEW EASY"
H.K.P.
SIZE
H.K.P.

Fig. 23.—Tool for Cutting off Bolts and Rivets.

Universal Tool

A particularly useful multi-purpose tool for the garage workshop is that known as the Eclipse 4S, made by Messrs. James Neill & Co., Ltd., Sheffield. This tool consists of a nickel-plated holder that has been designed to take no less than fifteen different tools, each one having a

TABLE 6.—TYPICAL TORQUE WRENCH MAXIMUM READINGS ON DIFFERENT CARS

Make	*Model*	*Cylinder Head*		*Connecting Rods*		*Main Bearings*	
		Torque lb./ft.	*Hex. in.*	*Torque lb./ft.*	*Hex. in.*	*Torque lb./ft.*	*Hex. in.*
Albion	114 to 125	79	—	66	—	—	—
	AZ and BY	84	—	33	—	—	—
	FT	66	—	33	—	—	—
	CX	18	—	66	—	—	—
Armstrong-Siddeley	16-h.p.	40	7/16	25	5/16	—	—
Bedford	26, 33, W	78–83	—	38–43	—	63–66	—
	27, 34, W	78–83	—	38–43	—	63–66	—
	K.M.O. "OW"	78–83	—	38–43	—	63–66	—
	H.C.V.	43–47	—	38–43	—	47–50	—
	J.C.V.	43–47	—	38–43	—	47–50	—
Ford	8-h.p.	35	9/16	35	1/2	50	5/8
	10-h.p.	35	9/16	35	1/2	50	5/8
	V8–30-h.p. (Iron)	60–65	11/16	40	9/16	65	3/4
	V8–30 h.p. (Alloy)	50	11/16	—	—	—	—
Gardner	L.W.	62·5	1/2	104	5/8	175	3/4
	L.K.	54	—	82	—	144	—
Guy	23 R.A.C. Vixen	90	7/16	85	1/2	90	1/2
	23 R.A.C. Otter	90	7/16	85	1/2	90	1/2
	20 R.A.C. Wolf	90	7/16	85	1/2	90	1/2
Hillman	Minx range	40	3/8	20–14	5/16	65–43	—
Humber	Hawk	55	3/8	20–14	5/16	65–45	—
	6-cyl. range	40	7/16	40–30	3/8	65–45	7/16
Sunbeam Talbot	2-litre	55	7/16	40–30	3/8	40–30	3/8
	10-h.p.	40	3/8	55–35	3/8	68–45	7/16
Jaguar	1½-litre 1938–40	92	1/2	37	3/8	83	1/2
	2½-litre 1936–40	92	1/2	37	3/8	83	1/2
	3½-litre 1938–40	62	7/16	37	3/8	83	1/2
Lea-Francis	12-h.p.	40	3/8	40	3/8	45	5/16
	12-h.p.	—	—	—	—	45	5/16
	14-h.p.	40	3/8	40	3/8	45	5/16
	14-h.p.	—	—	—	—	45	5/16
Leyland	7·4 litre six-cyl.	83–88	1/2	—	—	155–160	5/8
	0·6 litre six-cyl.	110–115	9/16	—	—	260–270	3/4
Riley	1½-litre	35	3/8	35	3/8	18	5/16
	2½-litre	55	7/16	40	3/8	70	1/2
	1½-litre	—	—	—	—	35	7/16
Sentinel	45 R.H.1	55	1/2	37·5	7/16	120	5/8
	45 R.H.2	55	1/2	37·5	7/16	120	5/8
	65 R.H.2	55	1/2	37·5	7/16	120	5/8
Standard	8-h.p.	35–38	5/16	35–38	5/16	90–100	7/16
	12-h.p.	90–100	5/16	35–38	5/16	90–100	7/16
	14-h.p.	90–100	7/16	35–38	5/16	90–100	7/16
Triumph	"1800"	90–100	7/16	35–38	5/16	90–100	7/16
Vauxhall	H.	43–47	—	38–43	—	47–50	—
	I.	43–47	—	38–43	—	47–50	—
	J.	63–66	—	38–43	—	66–71	—
Vulcan	6-V.F.	70	13/16	60	13/16	80	1
	6-V.F.	—	—	—	—	100	1 1/32
	9-V.F. A.	70	13/16	60	13/16	80	1
	9-V.F. A.	—	—	—	—	100	13/32

[*V. L. Churchill & Co., Ltd.*

TABLE 7.—TIGHTENING TORQUE FOR BOLTS, NUTS, AND SHACKLES ON "VANGUARD" CHASSIS

Operation	*Description*	*Material*	*Torque Recommended lb./ft.*	*Remarks*
Attachment of rear spring to axle	U-clip threaded $\frac{3}{8}$ in. 24 NF, with Simmonds nuts	High tensile. U.T.S. 50 tons per sq. in. min.	28–30	Pulled up to spring clamp plate
Attachment of rear spring to shackle and frame	Shouldered shackle pin, with $\frac{3}{8}$ in. × 24 NF. thread	Ditto	28–30	—
Attachment of rear shackle to frame	Shouldered shackle pin with $\frac{1}{2}$-in. × 20 NF. thread	Ditto	60–65	Crushing on M/S shackleplate against narrow shoulder of pin with excessive tightening
Attachment of front and rear shock absorbers, stabiliser bar, etc.	$\frac{7}{16}$ in. × 20 NF. bolts and nuts, or set-screws	Medium tensile. U.T.S. 40–55 tons per sq. in.	43–45	—
Cotter pins for front-suspension outer fulcrums, swivel pins, etc.	Taper pin with $\frac{5}{16}$-in. B.S.F. thread	Mild steel. U.T.S. 28 tons per sq. in. min.	14–16	—
Attachment of lower inner wishbone fulcrum, spring abutment plate, etc.	$\frac{3}{8}$ in. × 24 NF. bolts and nuts or set-screws	Medium tensile. U.T.S. 40–55 tons per sq. in.	28–30	—

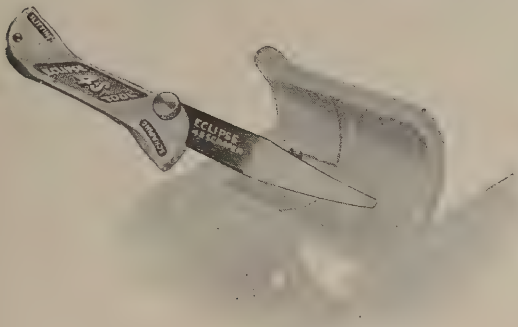
TIGHTENING TORQUE FOR BOLTS, NUTS, AND SETSCREWS ON "VANGUARD" ENGINE AND GEARBOX

Operation	*Description*	*Material*	*Torque Recommended lb./ft.*	*Remarks*
Main-bearing caps	$\frac{1}{2}$ in. × 13 NC. bolts to block	High tensile. U.T.S. 50 tons per sq. in. min.	90–100	—
Cylinder head	$\frac{7}{16}$ in. × 14 NC. and 20 NF. stud	Ditto	60–65	—
Flywheel attachment to crankshaft	$\frac{3}{8}$ in. × 24 NF. bolts into flywheel flange	Ditto	42–46	—
Connecting-rod caps	$\frac{3}{8}$ in. × 24 NF. bolts into rod	Ditto	42–46	—
Timing chain wheel attachment to camshaft	$\frac{5}{16}$ in. × 18 NC. bolts into camshaft	Ditto	24–26	—
Manifold attachment	$\frac{3}{8}$ in. × 16 NC. and 23 NF. stud	Mild steel. U.T.S. 28 tons per sq. in. min.	24–26	—
Oil-pump attachment, etc.	$\frac{5}{16}$ in. × 18 NC. and 24 NF. stud	Ditto	14–16	—
Rear oil-seal attachment, etc.	$\frac{1}{4}$ in. × 20 NC. set-screws	Medium tensile. U.T.S. 40–55 tons per sq. in.	8–10	—
Attachment clutch, oil filter, etc.	$\frac{5}{16}$ in. × 18 NC. bolts or set-screws	Medium tensile. U.T.S. 40–55 tons per sq. in.	20–22	—
Attachment of end plates timing cover, clutch housing, sump, etc.	$\frac{5}{16}$ in. × 18 NC. studs and setscrews	Mild steel. U.T.S. 28 tons per sq. in. min.	16–18	Some holes are tapped in alum. sealing block
	$\frac{5}{16}$ in. × 24 NF. bolts	Medium tensile. U.T.S. 40–55 tons per sq. in. min.	20–22	
Attachment of gearbox rear extension, front and top cover	$\frac{3}{16}$ in. × 18 NC. set-screws	Medium tensile. U.T.S. 40–55 tons per sq. in.	14–16	Tapped holes in alum. cases
Attachment of gearbox selector bush and interlock	$\frac{1}{4}$ in. × 20 NC. set-screw	Medium tensile. U.T.S. 40–55 tons per sq. in.	6–8	Tapped holes in alum. case

Notes: 1. All nuts are mild steel U.T.S. 28 tons per sq. in. minimum, except Simmonds nuts, which are medium tensile.

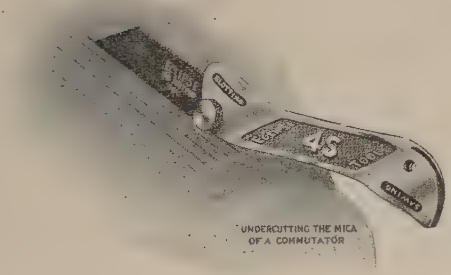
2. N.C.—American National coarse thread.
3. N.F.—American National fine thread.
4. U.T.S.—Ultimate tensile strength of material
5. To convert lb./ft. to lb./in. multiply by 12.

perforated triangular end which fits into a slot in the end of the holder. The tools provided with this outfit include six "Eclipse" double-edge slotting blades, two engineer's scrapers (one each of half-round and flat), and one engineer's belting and lead-slitting knife. It is possible with

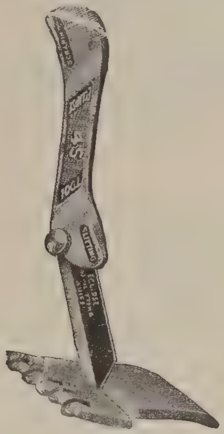


The Bearing Scraper Attachment

Short Saw for Cutting off Pins, etc., in confined places.



Wider Saw for Undercutting the Mica Insulation of Dynamo Commutator.



Knife-blade Attachment for Cutting Belts, Packing, and Gaskets.

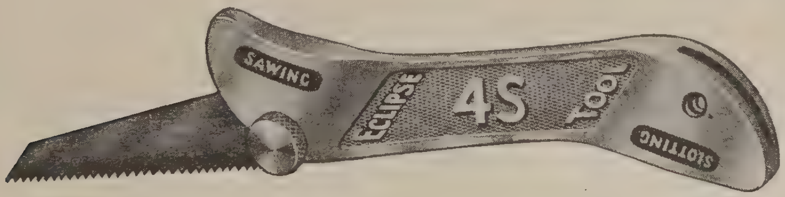


Fig. 24.—The "Eclipse" 4S Universal Tool and Some of its Uses.

this range of tools to do slotting, sawing, scraping, slitting and other engineering operations, plumbing, and general maintenance work. The tools are packed in a neat metal container, and are made from high-grade crucible tungsten steel, hardened and tempered. The outfit is retailed at quite a low figure, and it is possible to obtain replacements at a correspondingly low cost, if required. Fig. 24 shows the tool in question and illustrates some of its applications.

Two handy tools are shown in Figs. 25 and 26. The former shows a split-pin extractor, which consists of a kind of bent punch, the tapered end of which is inserted in the eye of the split-pin, and after the latter has been "closed," the extractor is pulled or tapped so as to withdraw the split-pin. The latter illustration shows a "round the corner" turnscrew, in which the two screw-driver edges are arranged at right angles to each other. With this device screws in awkward places, which cannot be got at with the ordinary long screw-driver, can readily be operated. The tool shown is 4½ in. long and is made in steel, hardened and tempered.

Fig. 27 shows a useful design of screw-driver which can be used for inserting or withdrawing screws in awkward places. In appearance it resembles the common type, but instead of a solid shank this consists of a piece of nickel-plated soft copper tubing, through the bore of which runs a flexible shaft drive from the handle (to which it is fixed) to the hardened-steel screw-driver blade. The rotation of the handle thus causes the rotation of the blade, or bit, no matter to what angle the copper tube is bent—within certain limits, up to about 90°. It is thus possible to insert screws in places which would be inaccessible to the ordinary screw-driver.

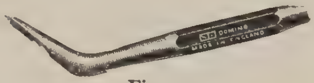


Fig. 25.

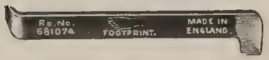


Fig. 26.

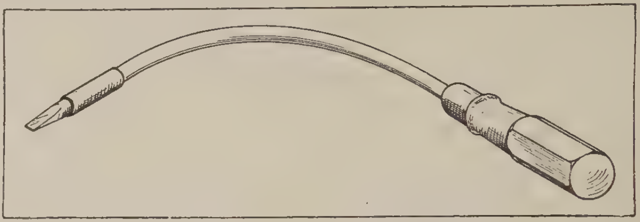


Fig. 27.—Flexible-shank Screw-driver.

The same principle has been applied to spanners, and also to drills, so that this method offers a distinct advantage over the ordinary ones.

Special Motor-vehicle Servicing Tools

Whilst the standard engineers' tools, such as spanners, wrenches, screw-drivers, punches, chisels, and all the tools generally to be found in the mechanical engineering workshop, are very useful for many straightforward dismantling and assembling jobs, experience with some of these tools on motor vehicles has shown that they are not always the best for their purpose, so that much time may be taken in servicing and repair work when using such tools. This experience has led the service engineers of motor manufacturers to devise complete sets of tools of special design eminently suited to rapid and efficient servicing jobs on their own vehicles. A considerable amount of the mechanics' time can thus be saved and the actual operations rendered much easier. It may be mentioned that certain tool and equipment manufacturers now specialise in the production of these special servicing tools and other parts for standard makes of motor vehicle.

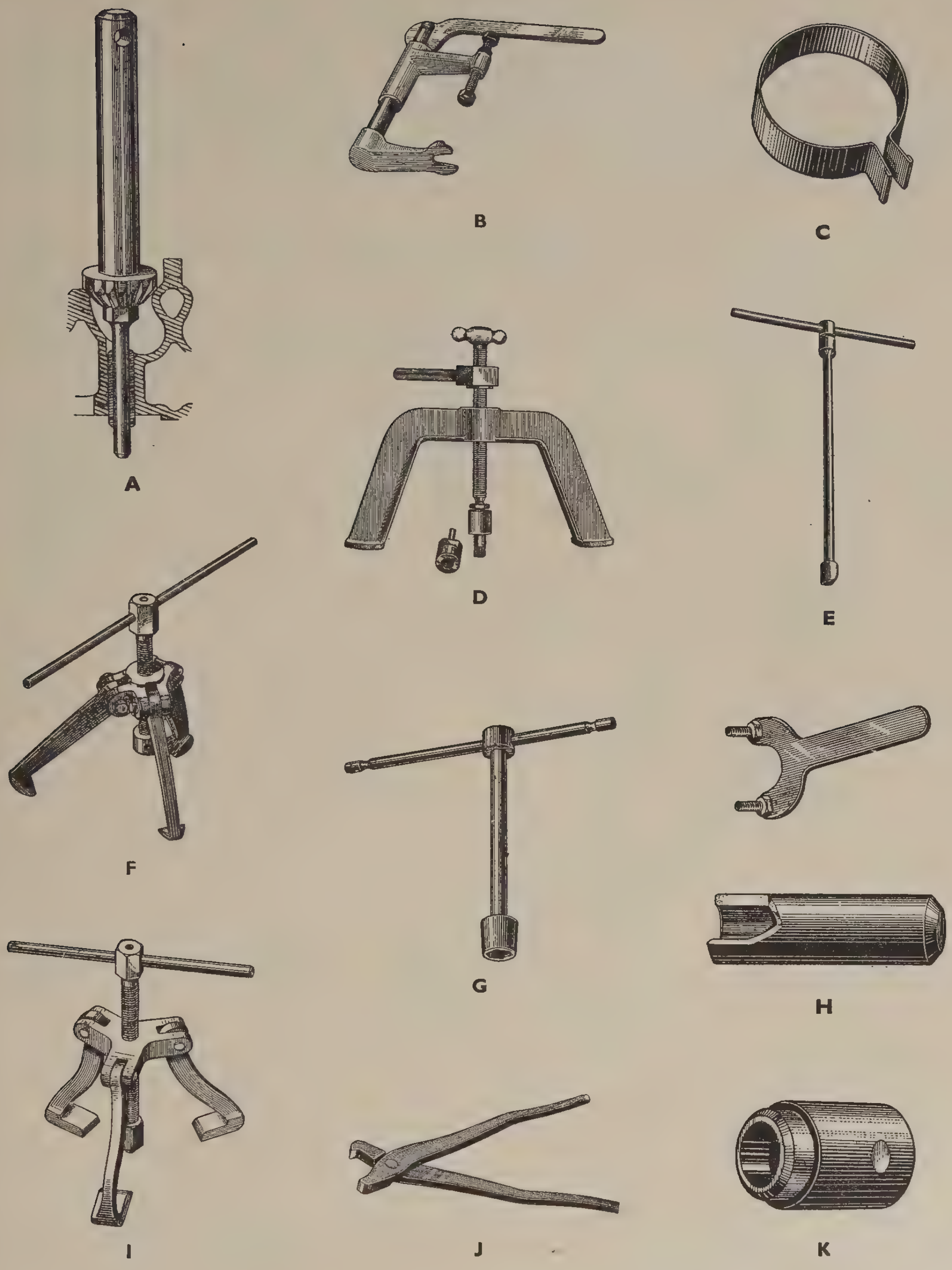


Fig. 28.—The Austin A40 Special Engine Tools.

A, Valve-seat Cutter. B, Valve-spring Lifter. C, Piston-ring Guide. D, Main Bearing Cap Extractor. E, Connecting Rod Bolt Spanner. F, Crankshaft Gear Extractor. G, Dynamo Pulley Nut Box Spanner. H, Fan and Dynamo Driving Pulley Drift. I, Fan and Dynamo Pulley Extractor. J, Connecting Rod Lock Washer Pliers. K, Front Cover Locating Bush.

An examination of typical sets of motor-servicing tools will usually show that these may be grouped into different classes according to the chassis component or unit concerned. Thus there are sets of tools for: (1) the engine unit; (2) the clutch; (3) the gearbox; (4) the front suspension and

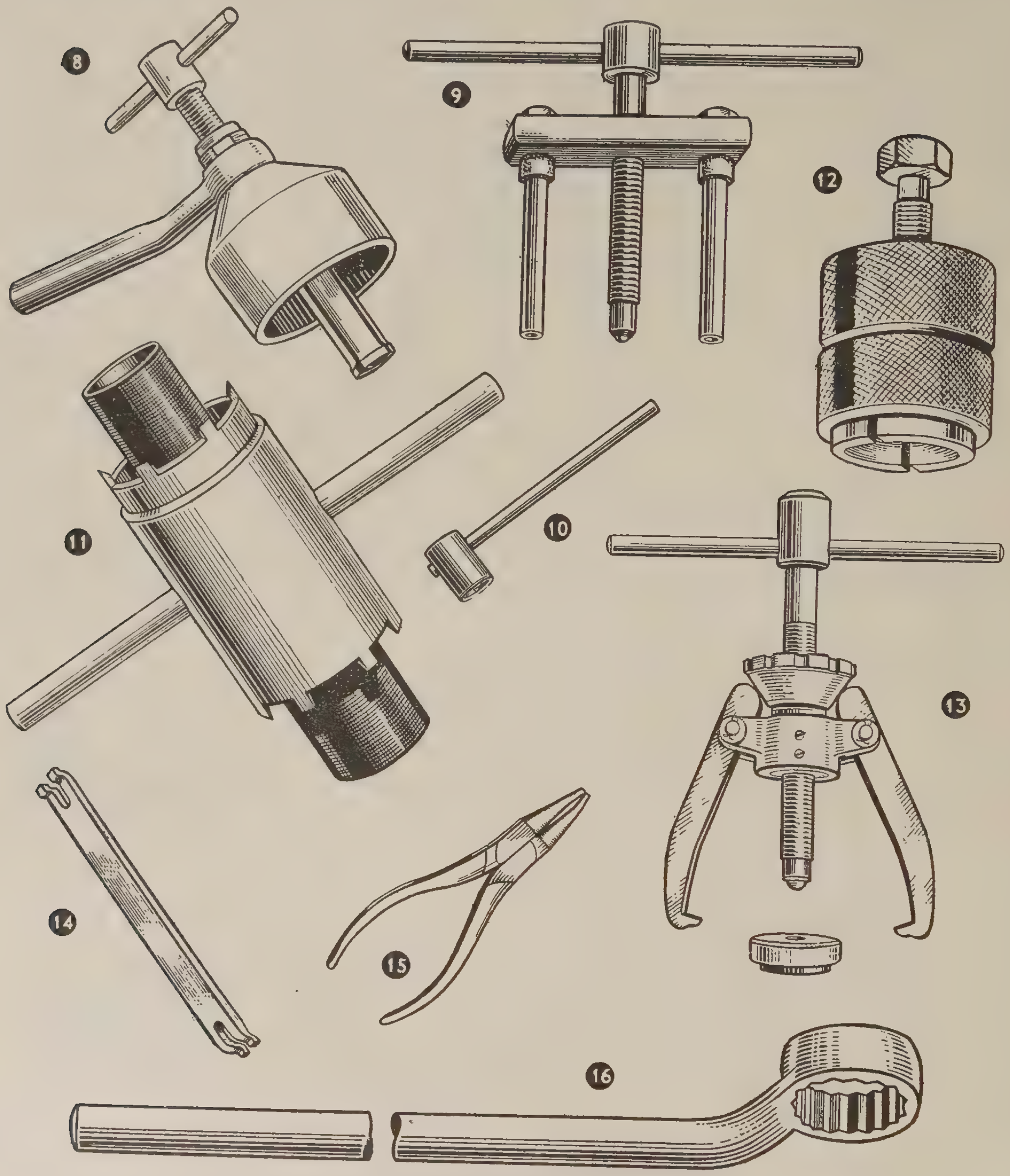


Fig. 29.—Set of Special Tools for Bedford Owl Vehicles.

8 Spigot Bearing Withdrawal Tool (Clutch). 9, Propeller Shaft Bearing Drag. 10, Gearbox Universal Joint Coupling Nut Spanner. 11, Rear Axle Hub Bearing Nut Wrench. 12, Rear Axle Pinion Inner Bearing Drag. 13, Rear Axle Differential Side Bearing Drag. 14, Rear Axle Spiral Drive Gear Adjusting Wrench. 15, Rear Axle Hub Bearing Circlip Pliers. 16, Rear U-bolt Nut Wrench.

hub; (5) the rear axle; (6) the steering and chassis; (7) the electrical system, including the ignition, charging, and starting units.

The Engine Unit.—The special tools supplied by the manufacturer for engine servicing include as a rule cylinder-head nut spanners, valve-spring

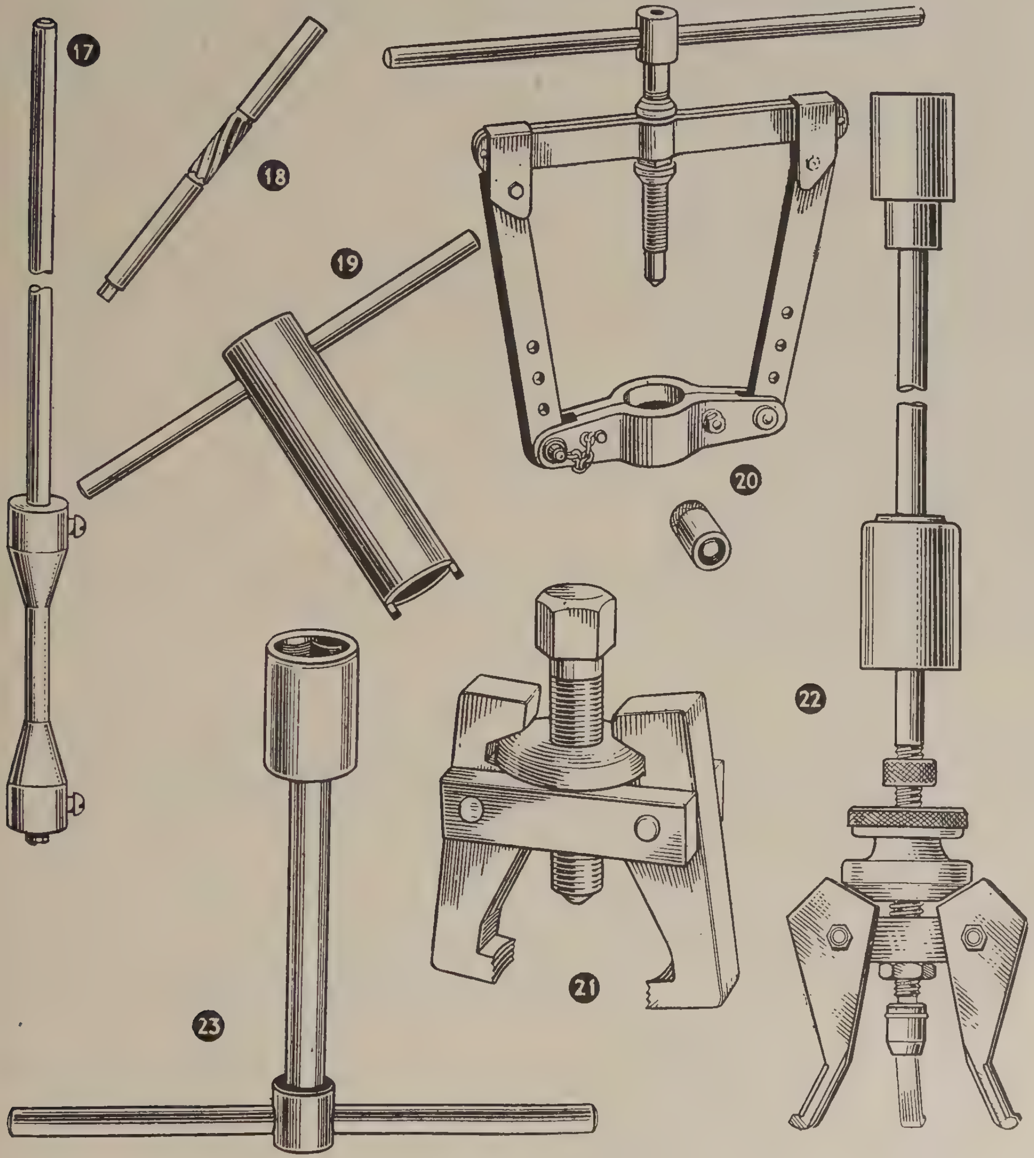


Fig. 30.—Special Tools for Front Axle, Steering Gear, and Brakes.

17, Front Axle Sighting Bars for checking Front Axle Beam. 18, Front Axle Pivot Pin Reamer. 19, Steering-wheel Nut Spanner. 20, Steering-wheel Extractor. 21, Steering Drop-arm Drag. 22, Steering-column Top Race Extractor. 23, Brake-wheel Bolt Inner-nut Wrench.

lifters, valve-seat cutters, pulley extractors, piston-ring compressors or guides, valve cotter withdrawal tools, bearing-cap extractors, shell-type bearing extractors, and some tools designed for important miscellaneous applications.

Although some of the tools mentioned are dealt with more fully in later chapters of these volumes, it is of interest to consider a typical set of engine servicing tools, namely those of the Austin A40 engine shown in Fig. 28. The descriptions of the various tools given in the caption are sufficiently self-explanatory, and they serve to show that each and every design of motor-vehicle engine requires its own special time- and labour-saving tools.

Special Tools for Other Units.—It is not proposed to describe each and every type of tool or equipment that has been designed to render the servicing of the various units of motor vehicles, since this would require a considerable amount of space, but it is proposed to give two further examples of sets of tools that have been made by Messrs. Jenks Bros., Ltd., under the name of " Britool," for the Bedford OWL vehicles.

Fig. 29 illustrates a group of special tools for dismantling, adjusting, or reassembling the clutch, gearbox, propeller shaft, and universal joints, and the rear-axle assemblies of the vehicles in question.

The second example that has been selected refers to the special tools used for the Bedford front axle, steering gear, and brakes; these tools are shown in Fig. 30.

An examination of the various special tools illustrated and described on the preceding pages will serve to indicate that these include wrenches, hub, pulley and ball-race extractors and adjuster devices.

Increasing Diameter of Worn Shafts

It frequently happens in the garage workshop that although the rest of the shaft, rod, or axle is in perfectly satisfactory condition, one end which has been subjected to wear is below size, and therefore the whole shaft is practically useless in the ordinary way.

There are, however, two important methods of salving such worn parts so that they can be made practically as good as new again.

One of these methods is to *electro-plate or metal-spray the worn surface* with nickel or chromium until a sufficient thickness has been built up to enable the part in question to be turned in the lathe or ground to its original unworn dimensions.

The subject of building up worn parts by the electro-deposition method is dealt with more fully in Volume III of this publication.

The other method is to increase the diameter of the worn part by means of a special knurling tool of the type illustrated in Fig. 31. This tool has a pair of hardened knurled rollers mounted so as to be free to rotate on their pins. One of the latter is fitted to the fixed member of the tool; the other is mounted in a sliding member which can be moved in a guide in the other fixed member, by means of a square-threaded screw operated by the tommy-bar shown.

The tool is clamped to the rod or shaft, a suitable pressure is applied to the knurling rollers by means of the screw, and the whole tool is rotated around the shaft. This causes a large number of small "knurls" or projections to appear round the circumference of the shaft so that its effective diameter is increased.

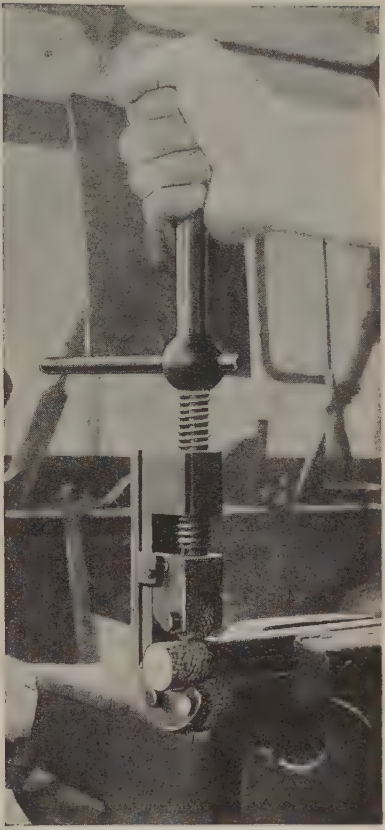


Fig. 31.—The H.F. Knurling Tool for Increasing Shaft Diameters.

This is a very useful method of neutralising wear in the case of shafts carrying ball bearings, where movement of the shaft race has caused the shaft to wear.

It is not so efficient, of course, as the electro-plating method, since it only gives about one-third to one-half the effective surface, and the amount by which the diameter can be increased is limited.

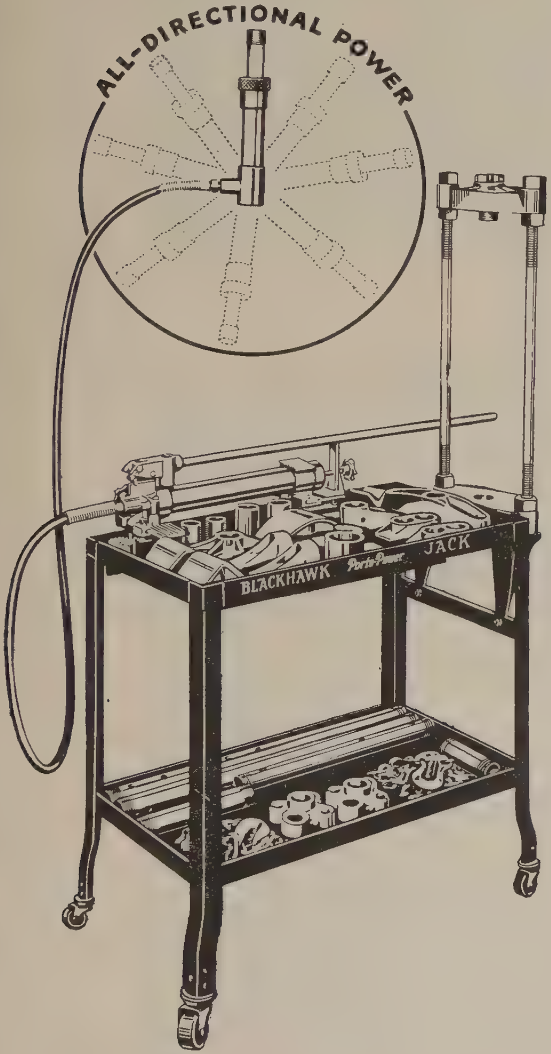


Fig. 32.—The "Porto-Power" Hydraulic Tool.

The "Porto-Power" Hydraulic Tool

An extremely useful apparatus for garage-workshop purposes is

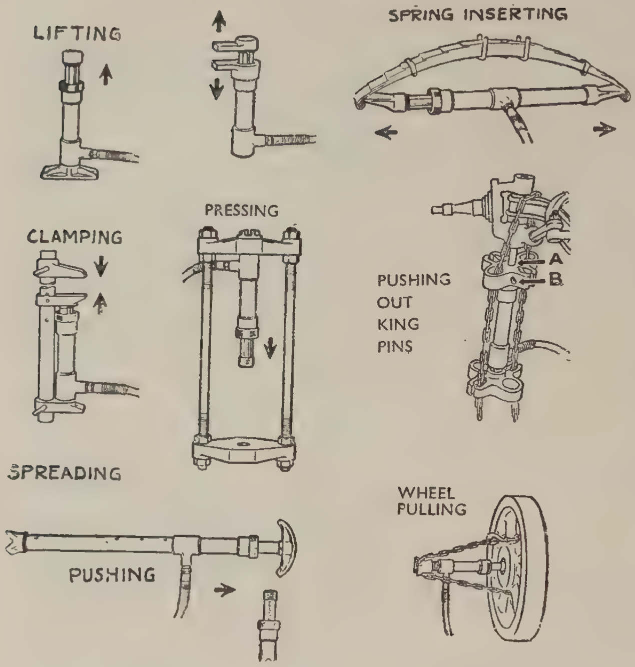


Fig. 33.—Showing some Typical Uses of the Porto Tool.

that known as the "Blackhawk Porto-Power"[1] unit. It consists of two principal units, namely an hydraulic jack, or ram, and a pump and reservoir unit.

The ram unit is of cylindrical shape, $11\frac{3}{8}$ in. long by $2\frac{1}{4}$ in. in diameter; it contains a plunger having a travel of $6\frac{3}{8}$ in., and under the pressure exerted by the hand pump will give a total force effect of seven tons; it weighs only 10 lb.

The pump and reservoir unit are separate and are connected to the ram by means of a 6-ft. length of wire-mesh oil-proof rubber hose which will withstand a pressure of 15,000 lb. per sq. in. without leaking.

The pressure exerted by the ram, and the travel of the latter, are applied in a wide variety of ways, some of which are illustrated here; in

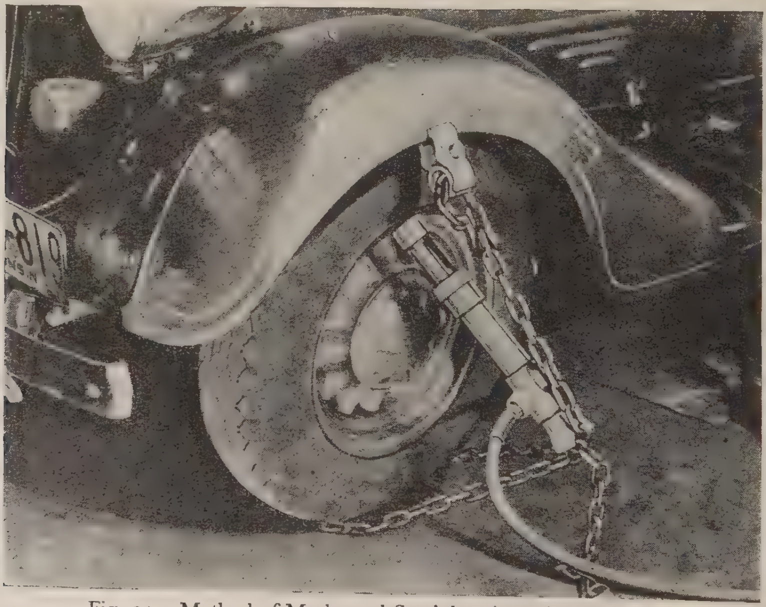


Fig. 34.—Method of Mudguard Straightening with Porto Tool.

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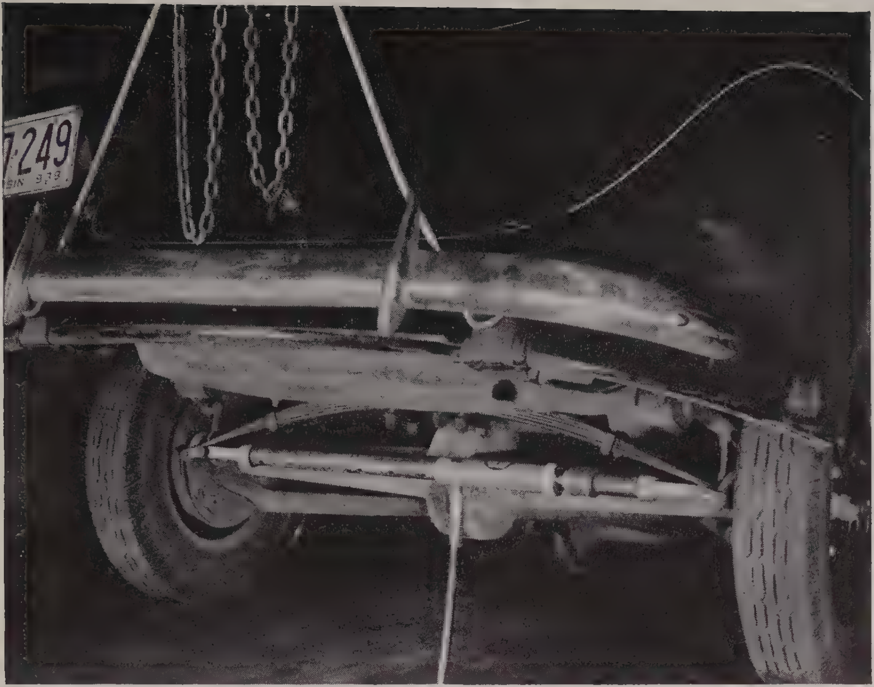
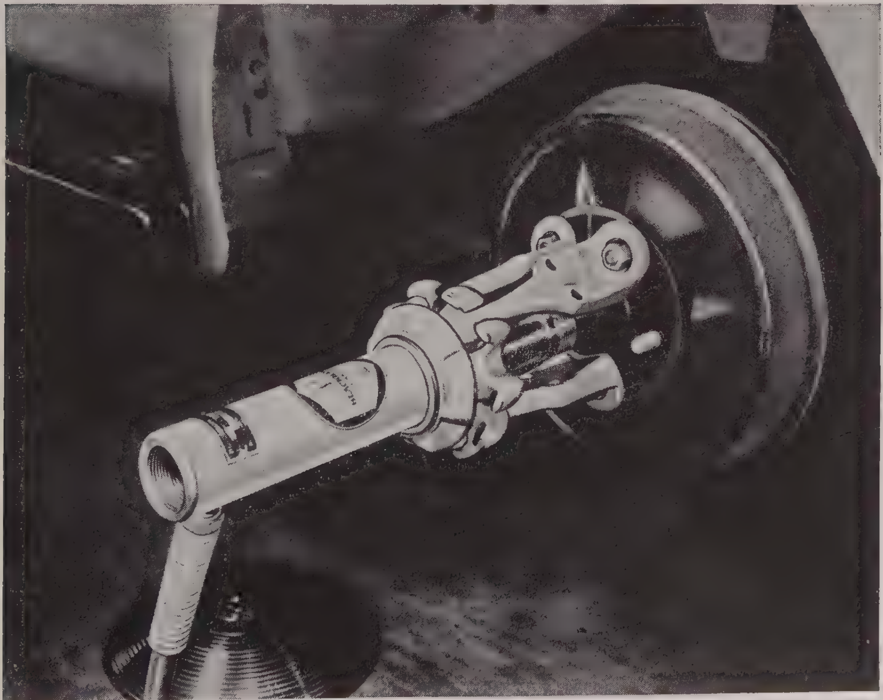
[1] E. P. Barrus, Ltd., Acton, London, W.3.



THE PORTO-POWER UNIT, AS USED FOR SPREADING TRANSVERSE LEAF SPRING PRIOR TO ITS REMOVAL.



THE PORTO-POWER UNIT IN USE FOR WHEEL-HUB EXTRACTION PURPOSES.

order to apply this method a number of attachments are available. Fig. 32 shows the complete unit mounted on its stand, some of the accessories being illustrated on the trays.

Among the uses of this device, the following may be mentioned: lifting car as ordinary jack; pressing or pulling; clamping; pushing out king-pins (Fig. 35); wheel pulling; chassis-frame straightening; spring inserting and removal; mudguard straightening (Fig. 34); body straightening; pressing bushes in or out of place; inserting valve-seats; presswork; forcing gudgeon pins out, etc. Two further illustrations showing the use of this portable power unit are given on the Plate facing page 46.

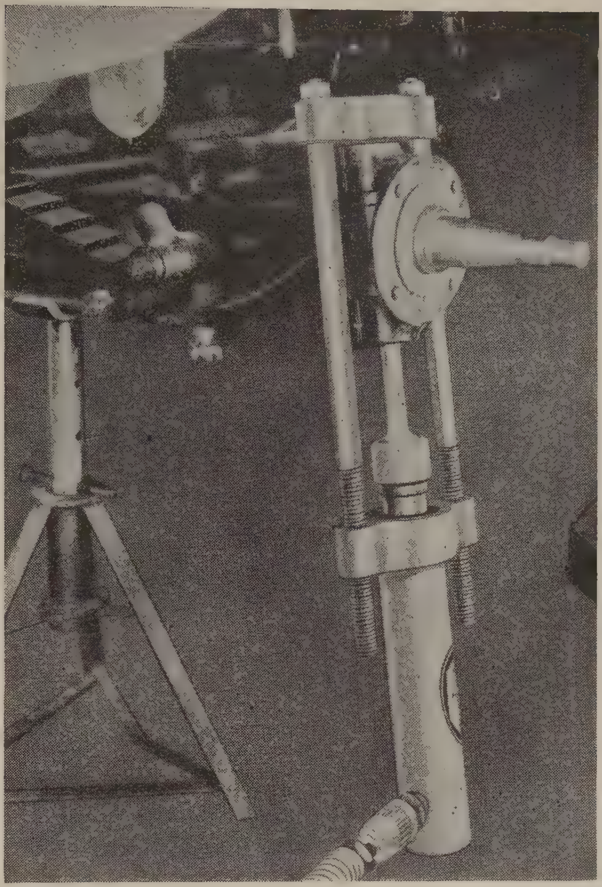


Fig. 35.—The "Porto-Power" Unit used for extracting King Pins from Front Axle.

CHAPTER 3

MOTOR ENGINEERING MEASURING DEVICES

In view of the high degree of precision employed by motor-vehicle manufacturers in the machining and finishing of the components of the engine and transmission, etc., it is necessary when servicing these vehicles to work to the same limits of fit and finish. For this purpose the motor mechanic and machinist must be familiar with the usual range of measuring instruments and devices and know how to employ and read these. In the present chapter it must be assumed that the reader is already familiar with the use of the more common measuring devices, including the engineer's rule, callipers, dividers, steel tapes, and the simple calliper gauge (not of the vernier pattern).

Feeler Gauges

One of the most useful measuring gauges used by the motor mechanic is the feeler gauge illustrated in Fig. 36. It consists of a number of blades or strips of polished steel encased in a pair of strong side pieces, somewhat in the form of an ordinary pocket-knife. Each blade is of a different thickness, the smallest being 1½-thousandths of an inch, and the others, respectively, 2, 3, 4, 6, 8, 10, 12, 15, and 25-thousandths.

This gauge is useful for measuring the clearances between metal parts; for example, the valve tappet clearances can readily be measured or set with the appropriate feeler. Any clearance can be measured by using combinations of the blades; thus 5-thousandths with the 2 and 3 feelers, 7-thousandths with the 3 and 4 feelers, 13-thousandths with the 10 and 3 feelers, and so on.

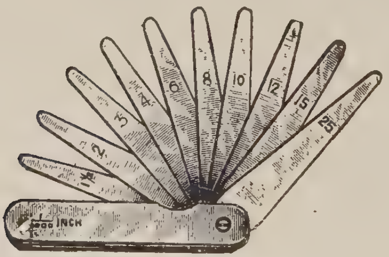


Fig. 36.—Feeler Gauge.

Feeler gauges are now available in a wide range of sets, from the simple pocket set of six blades to the more elaborate eighteen blades. The latter has its blades arranged in selected thicknesses so that measurements can be obtained up to $\frac{25}{1000}$ in.

Limit Feeler Gauges

A more recent improvement in feeler gauges is the " Feelimit " pattern having eighteen blades of stainless steel arranged so that there are nine blades at each end (Fig. 37). The blades on the left are in marked thicknesses of 2, 4, 6, 8, 10, 12, 15, 20, and 25-thousandths inch; those on the right of 1½, 3, 5, 7, 9, 11, 14, 19, and 24-thousandths inch. This arrangement of the blades doubles the usefulness, for those at one end can be used as the " high " and those at the other end as the " low " limit blades.

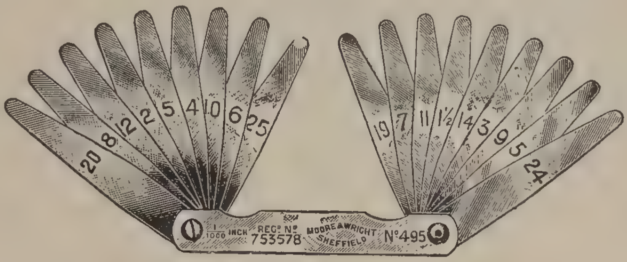


Fig. 37.—The " Feelimit " Set of Feeler Gauges.

If it is desired to set a valve tappet to $\frac{6}{1000}$ in., the No. 6 blade at one end and the No. 7 one at the other should be drawn out and used as a " Go " and " Not Go " gauge.

Piston Feeler Gauges

Another useful set of feeler gauges is the *piston feeler* one, shown in Fig. 38. These long narrow blades are arranged in a set of eight to obtain thickness or clearance measurements from 1½ in. to $\frac{5}{1000}$ in. in steps of one half-thousandth inch.

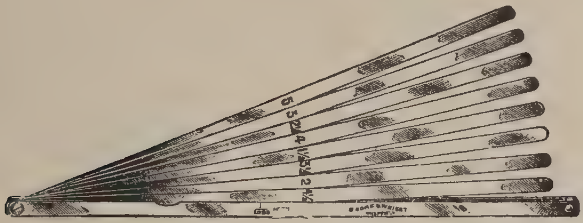


Fig. 38 —Piston Feeler Gauges. (Moore and Wright.)

With these feelers, it is a comparatively simple matter to measure the clearance between a piston and its cylinder. As an example, supposing a 3-in. cylinder with aluminium piston has a new clearance of 4½-thousandths. The feeler gauge marked 4½, when put down the side of the cylinder, should just hold the piston in position. When the feeler is drawn out, the piston should just slide down. For larger clearances than $\frac{5}{1000}$ in. several blades can be used together.

Typical Uses of Feeler Gauges

Although the more important uses of feeler gauges are mentioned throughout these volumes it may here be of interest to the reader to describe some typical instances of feeler-gauge application in motor-vehicle servicing, notably in connection with the engine unit.

Amongst other uses is that of measuring the fit of the piston in its cylinder, in which case the feeler gauges shown in Fig. 38 are employed in the manner shown in Fig. 39 (left illustration). As will be mentioned later in this volume, a spring balance is sometimes used, so that the exact pull or force needed to move the feeler between the piston and cylinder can be specified for this test.

Another application, see Fig. 39 (right illustration), is that of measuring piston-ring gaps with the piston ring in position in its cylinder. Apart from the previously referred to use of the feeler gauge for measuring valve-stem and tappet clearances, this type of gauge is used for checking end clearances of big-end and main crankshaft bearings in relation to their crankshaft journals. It is usual to allow a small amount of side float between the bearing and the sides of the crank journals; this is generally a matter of a few thousandths of an inch, and is readily checked with the feeler gauge.

The end float of the camshaft in its bearing is also checked in a similar manner against the manufacturer's recommended amount.

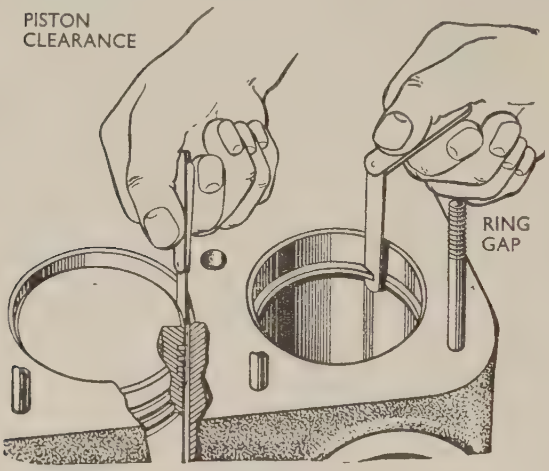


Fig. 39.—Illustrating uses of Feeler Gauge.

The diametral clearance of oil pump gearwheels and also their end clearances are tested (for wear effects) with the feeler gauge.

Various bearing and gear clearances in the transmission members are also measured in a similar manner and compared with the manufacturer's values.

In the ignition system the contact-breaker gap and also the sparking-plug gaps are invariably tested with feeler gauges. The method of checking sparking-plug gaps in the case of Hillman engines is illustrated in Fig. 40. Usually, the car manufacturers supply a special three-blade feeler gauge for measuring the valve clearance, contact-breaker and sparking-plug gaps, respectively.

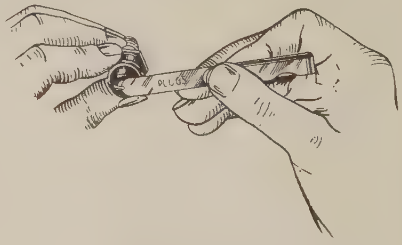


Fig. 40.—Checking Sparking Plug Gap with Feeler Gauge.

Care of Feeler Gauges

In connection with the use of feeler gauges, the feelers must be kept scrupulously clean, as any grit between or on the blades may impair the accuracy of the measurements. No moisture should be allowed to rest on the blades. After use or when storing, the blades should be wiped with an oily rag. It should be mentioned that all feeler gauges are not made in the same series of thicknesses; this is a point for consideration when purchasing.

Micrometer Calliper Gauges

The ordinary micrometer gauge, such as the Starrett or Moore & Wright pattern, will be found exceedingly useful in connection with the measurement of automobile parts, whether for new parts, repairs, or for wear indications. These micrometers enable diameters or thicknesses to be measured in thousandths of an inch, and any measurement within their range can be "set" or locked by tightening the knurled nut shown inside the jaws on the right. A ratchet stop device is fitted for the purpose of ensuring uniformity of pressure when the measuring point is screwed down on to the part to be measured. The small knurled screw shown on the extreme right, at F in Fig. 41, enables this device to be used, and it is simply turned until the measuring point touches the object, when any further turning merely causes the ratchet to operate so that the micrometer screw will not screw down any farther.

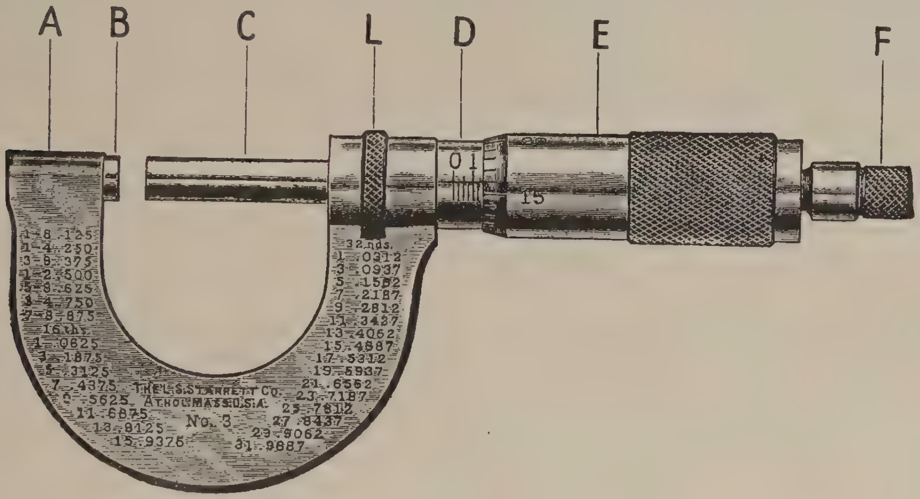


Fig. 41.—The Micrometer Caliper Gauge.

Starrett micrometers suitable for automobile measurement purposes are made in the following sizes: to 1 in., 2 in., 25 mm. and 50 mm. Readings to within $\frac{1}{1000}$ in. can be obtained with these micrometers.

How to Read a Micrometer

The essential components of the English or inch-type of micrometer calliper gauge are shown in Fig. 41, in which the ratchet type is illustrated. The spindle C is integral with the thimble E on the inside at the right end portion. The part of the spindle which is concealed and protected against the ingress of dust within the sleeve is threaded to fit a nut in the frame A.

Thus, as the milled portion of the thimble E is rotated the spindle C moves towards or away from the fixed hardened flat-faced anvil B. The object to be measured is placed between the ends of B and C and the latter contact is screwed towards the object until it makes sliding contact, when the readings of the scales on D and E are taken. F denotes the ratchet device mentioned previously.

The screw of the micrometer has 40 threads per inch, so that the amount the spindle moves axially for one complete revolution of the thimble is $\frac{1}{40}$ in., or $\frac{25}{1000}$ in. The longitudinal scale on D is graduated in $\frac{1}{10}$-in. divisions, each of which is subdivided into four equal parts, i.e. $\frac{1}{4} \times \frac{1}{10} = \frac{1}{40}$ or $\frac{25}{1000}$ in.

The bevelled edge of the thimble is graduated into 25 equal divisions, so that one complete turn of the thimble is equivalent to 25 parts on the scale, and since we have seen that one turn of the thimble moves the measuring spindle by $\frac{25}{1000}$ in., then each single division on the thimble scale must move the spindle by $\frac{1}{25} \times \frac{25}{1000}$, or $\frac{1}{1000}$ in.

We are thus able to make measurements to within $\frac{1}{1000}$ in. accuracy. The rule for reading the micrometer is as follows:

(1) First read the whole number of $\frac{1}{10}$ths on Scale D.
(2) Then read the additional number of $\frac{1}{40}$ths on Scale D.
(3) Finally read the number of divisions on thimble scale against the longitudinal line on Scale D.

The three readings thus taken when added together give the final or complete reading of the gap or distance between B and C.

In the example shown by the scale readings of the micrometer illustrated, there is one $\frac{1}{10}$-in. graduation exposed on the sleeve scale. In addition, there is one subdivision of $\frac{1}{40}$-in. (·025 in.). Finally, the 16 mark on the thimble scale comes opposite the horizontal line on the sleeve scale. Applying the preceding rule we get:

(1) Whole number of $\frac{1}{10}$-in. divisions on D = 1, i.e. $\frac{1}{10}$ = ·100 in.
(2) Number of $\frac{1}{40}$-in. divisions on D = 1, i.e. $\frac{1}{40}$ = ·025 in.
(3) Number of $\frac{1}{1000}$-in. divisions on E = 16 = ·016 in.

Total reading = ·141 in.

Therefore the distance between the parallel contacts on the anvil B and spindle C is ·141 in.

In order to familiarise the reader with the method of reading micrometers, two further examples are given in Fig. 42. By using the system previously described for reading the micrometer scales, the results are as follows:

Upper diagram reading = ·202 in.
Lower diagram reading = ·270 in.

The Metric Micrometer.—In view of the fact that the motor engineer has to deal both in the English and metric, or Continental, systems of measurement, it is as well for him to know how to read the micrometer graduated in millimetre units and subdivisions.

Fig. 43 shows the scale of a typical micrometer with which readings can be taken to within $\frac{1}{100}$ in. (or ·01 mm.). In this case the sleeve B is divided into whole millimetre divisions (above the horizontal line) and half-divisions below this line. In reading the scale, the number of whole divisions is first read off, and if there is a half-division exposed between the last whole division and the thimble scale bevelled edge, this is added to the whole divisions. The thimble scale A is divided from 0 to 50 in equal divisions. Since the spindle screw thread has a pitch of $\frac{1}{2}$, or ·5 mm., each complete turn of the thimble moves the spindle by a distance of ·5 mm.

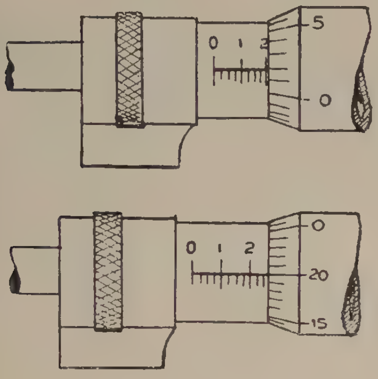


Fig. 42.

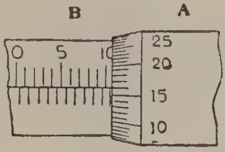


Fig. 43.—The Metric Micrometer Scales.

Each division on the thimble scale is equal to $\frac{1}{50} \times ·5 = \frac{1}{100}$ or ·01 mm.

To read the metric micrometer:

(1) Read the number of whole divisions on sleeve scale (1 mm. divisions).
(2) Read the additional half-division (·5 mm.) if exposed.
(3) Read the thimble scale ($\frac{1}{100}$ or ·01 mm. divisions).

The sum of these readings gives the final result required.

In the example illustrated in Fig. 43, the readings are as follows:

(1) Number of whole divisions (10) = 10·00 mm.
(2) Half-division exposed = ·50 mm.
(3) Reading on thimble scale (16) = ·16 mm.

Complete reading = 10·66 mm.

Other Types of Micrometer Scales

Where greater precision of reading diameters or distances between parallel surfaces is required it is necessary to use micrometers having scales that can be read to within $\frac{1}{10,000}$ or ·0001 in. The principle employed is to use, in addition to the usual sleeve and thimble scales, a third vernier scale whereby it is possible to read to $\frac{1}{10}$ division on the thimble scale, i.e. $\frac{1}{10} \times \frac{1}{1000} = \frac{1}{10,000}$ in. or ·0001 in.

Another design of micrometer has an additional barrel or thimble scale which is used as a check on the readings of the sleeve and thimble scales. This obviates the possibility of making mistakes in reading the ordinary micrometer.

The Vernier Calliper

This instrument is a marked improvement upon the ordinary calliper and also the simple calliper gauge that is shown in Fig. 44. With the latter it is possible only to read to within $\frac{1}{32}$ in. or ·03125 in. The instrument in question has a fixed jaw, with the rule-type scale graduated in $\frac{1}{32}$-in. and $\frac{1}{2}$-mm. divisions attached. The sliding scale is moved along until its jaw touches the object to be measured and held against the fixed jaw. The sliding scale is then clamped with the screw shown, and the reading is taken on the bevelled edge of this scale, shown on the left in Fig. 44.

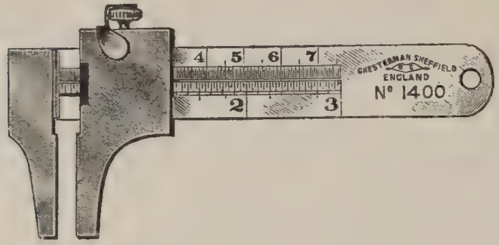


Fig. 44.—The Calliper Gauge.

Fig. 45 illustrates the British Standards vernier calliper, and it shows also the correct names of the various parts. With this instrument it is possible to take either inside or outside measurements to within $\frac{1}{1000}$ in. The principle of the vernier scale is illustrated in Fig. 46, which shows parts of the fixed scale F and the sliding scale S.

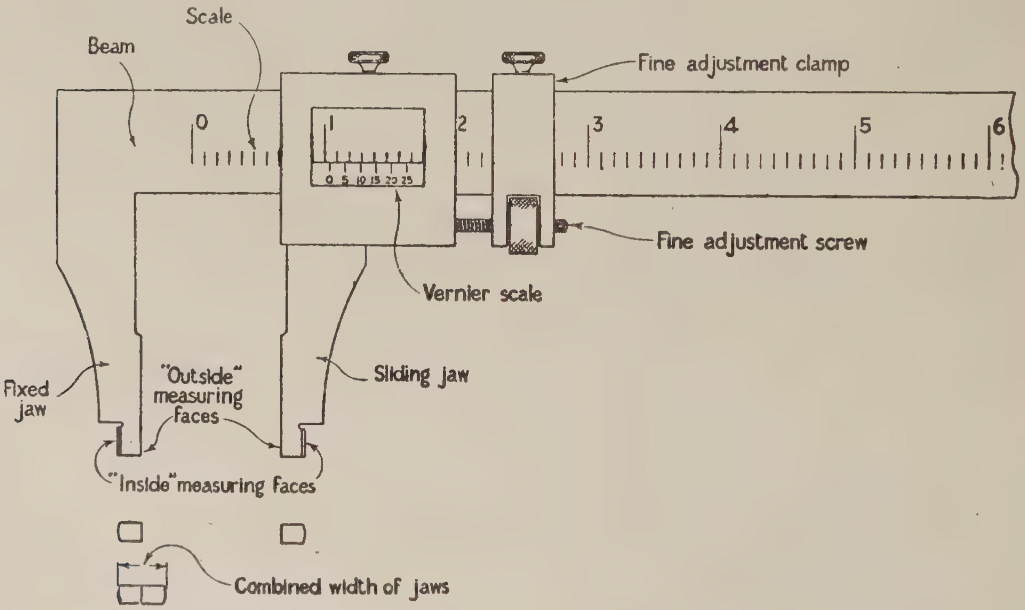


Fig. 45.—The British Standards Vernier Calliper. Parts and their Names.

The fixed scale is graduated in $\frac{1}{10}$-in. divisions, each of which is subdivided into four equal divisions of $\frac{1}{40}$, or ·025 in. each.

The sliding scale below is graduated into 25 divisions numbered 0, 5, 10, 15, 20, and 25, and it is arranged that these 25 divisions on the vernier occupy the same distance as 24 divisions on the fixed scale.

The difference between the width of one of the 25 spaces on the vernier and one of the 24 spaces on the fixed scale is $\frac{1}{25} \times \frac{1}{40} = \frac{1}{1000}$ or ·001 in. If the zero mark of the vernier is set so as to coincide with the zero mark on the fixed scale, then the first line to the right on the vernier will differ from the first on the fixed scale by $\frac{1}{1000}$ in.; the second lines by $\frac{2}{1000}$; the third lines by $\frac{3}{1000}$, and so on, until the 25 line on the vernier coincides with the 24 line on the fixed scale.

To read the instrument, first note how many whole inches, $\frac{1}{10}$ and $\frac{1}{40}$ in., there are to the left of the zero on the vernier scale. Then note the number of divisions there are on the vernier, from its zero, until the lines on the vernier exactly coincide with a line on the fixed scale. This number (on the vernier scale) gives the number of $\frac{1}{1000}$ in. that must be added to the fixed-scale reading to give the total reading corresponding to the distance between the fixed and sliding jaws.

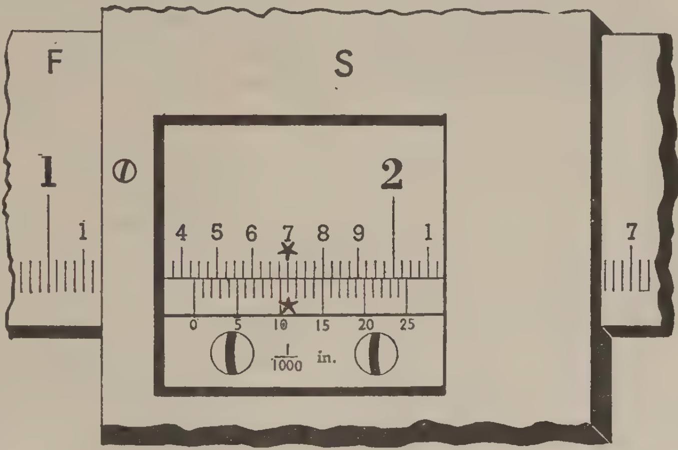


Fig. 46.—Illustrating Principle of Vernier Calliper Scales.

In Fig. 46 the fixed-scale reading up to the zero line of the vernier scale is $1\frac{4}{10}$ plus $\frac{1}{40}$ in. = 1·425 in. An examination of the two scales will also show that the eleventh line on the vernier coincides with the seventh line on the fixed scale.

In Fig. 46 these coincident divisions are marked, for explanation purposes only, with stars; the latter do not, of course, appear on the actual vernier.

From the preceding explanations it follows that the 11 divisions to coincidence correspond to $\frac{11}{1000}$, or ·011 in., that must be added to the fixed-scale reading, namely 1·425 in., in order to obtain the complete reading. Thus:

$$\text{Complete reading} = 1{\cdot}425 \text{ in.} + {\cdot}011 \text{ in.} = 1{\cdot}436 \text{ in.}$$

Micrometer Depth Gauge

It is often required to ascertain quickly and accurately the depth of a hole below a machined surface in automobile work. For this purpose the type of depth gauge shown in Fig. 47 is suitable.

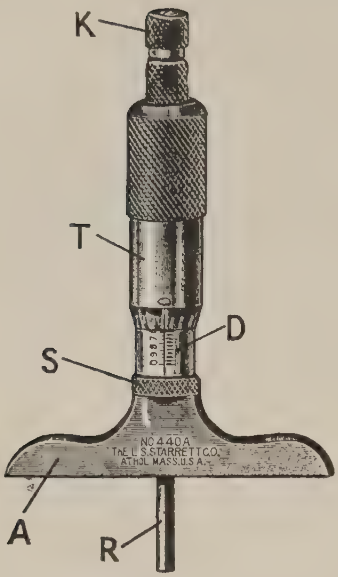


Fig. 47.—The Micrometer Depth Gauge.

This micrometer depth gauge (Fig. 47) has a measuring rod R and a flat anvil member A. The rod is moved down into the hole by means of the micrometer screw. It will be noted that the instrument uses exactly the same spindle, sleeve D, and thimble T members as in the ordinary $\frac{1}{1000}$-in. type of micrometer calliper, and is therefore read off in a similar manner. In order to accommodate the instrument to various depths of hole beyond the usual 1-in. travel of the spindle a set of extension bars is employed to fit into the spindle unit. The depth gauge is provided with a ratchet member K which comes into operation when the small knurled knob is rotated; there is also a locking screw, S, for clamping the spindle.

The Dial Gauge

Although the dial gauge is used, normally, in engineering workshops it has also important applications in motor-servicing operations as a means of checking the alignment of different components; typical instances of its use are to be found later in these volumes.

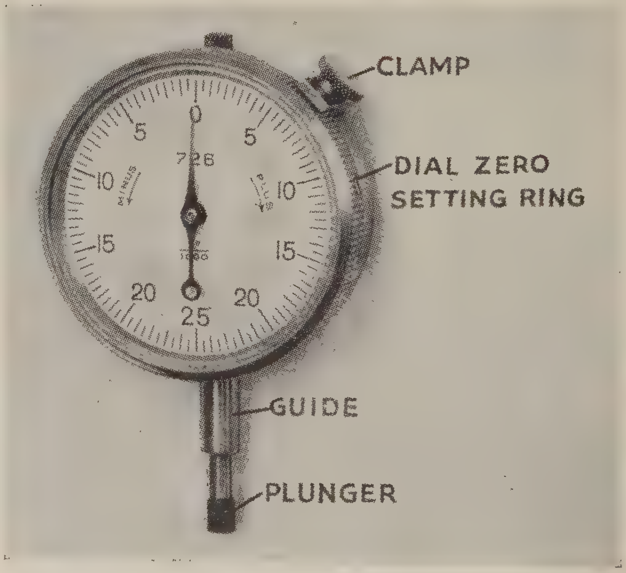


Fig. 48.—The Baty Dial Gauge.

The dial gauge (Fig. 48) comprises a casing within which the needle-actuating mechanism is located. The casing or body of the gauge is usually fixed to some convenient stand, such as a scribing-block, and the plunger—which is the measuring part of the instrument—is brought into contact with the object to be checked. The plunger can slide in its guide in the dial gauge by a limited amount, namely $\frac{1}{40}$ in. in the instrument shown in Fig. 48, and its movement is magnified by means of a lever or gear mechanism within the casing, so that the needle gives a much greater corresponding movement. The dial is graduated in $\frac{1}{2000}$-in. or half-thousandth-inch divisions, of which there are 100 in all, but as the particular instrument described is intended to show plus and minus readings on either side of the zero, the $\frac{1}{1000}$-in. graduations are only from 0 to 25 on either side. There is a milled ring to allow the scale to be set with its zero division against the needle for each application of the gauge. At the back of the gauge, but not shown in Fig. 48, there is a projection having a hole of about $\frac{1}{4}$ in. diameter, as a rule, for clamping the gauge to its support.

The dial gauge has the big advantage over the other forms of measuring instruments described as being a universal gauge since it can be fitted to various kinds of mountings, which greatly extends its range. Thus it can be clamped above a machined metal surface, and will then measure thicknesses or diameters of objects placed on the table. Or it can be held in a clamp, so that it can be adjusted over a cylindrical object such as a crankshaft, or can be located inside a cylindrical member such as a brake drum or clutch casing, and can then be used to measure out-of-round, or eccentricity, bearing clearances, or errors in flat surfaces. It can also be fitted to a lathe tool-post or scribing block column, and used to check the accuracy of work mounted in the lathe or of turned work in place in the lathe.

It must, however, be emphasised that the dial gauge is used mainly *for measuring differences of*, not absolute, measurements. It can, however, be employed in the latter sense if a standard cylindrical or block gauge is first used to set the distance of the plunger end from the measuring surface; the gauge needle is then arranged to read zero on its scale. All subsequent readings of the dial gauge will then represent plus or minus differences from the standard or zero reading.

It may also be mentioned that the dial gauge has been used in suitable supports for measuring cylinder bores and crankshaft diameters; indeed, the dial-pattern cylinder gauges can be regarded as special applications of the ordinary dial gauge.

Cylinder Gauges

One of the most frequent measurements of an accurate nature which the motor engineer has to make is in connection with the internal diameters of the cylinders. In this way any wear, ovality, or non-uniformity of wear with depth, such as taper effect, can be ascertained.

Whatever device is employed, it is necessary to be able to measure the exact diameter at any part of the cylinder, and with facility. The cylinder gauge should preferably be of the " set " type—that is to say, should set itself to the correct reading or give an outside indication as it is moved up and down or around the cylinder. Cylinder gauges are arranged to give readings to $\frac{1}{1000}$ in.; in some cases it is possible to estimate the gauge readings to within $\frac{1}{4}$-thousandth of an inch.

The various types of internal measurement or cylinder gauges available for motor engineering purposes include the following: (1) telescopic gauges; (2) bar-type micrometers; (3) dial gauges carried on sled members; (4) dial gauges on extension members for reading outside the hole to be measured; and (5) miscellaneous types depending upon different measuring principles.

The gauges mentioned under (1) and (2) are indirect-reading ones, and for each particular setting it is necessary to work out the true diameter. Whilst these gauges are relatively inexpensive, they require considerably more time to take a set of cylinder-bore readings than the dial-gauge pattern; moreover, there is always the possibility of errors in the working out of the final readings. For these reasons the dial type of cylinder gauge is definitely to be preferred, since there are no calculations to be made, and a cylinder bore can be explored in all directions expeditiously.

Of the available cylinder dial gauges, those having the dials outside the bore during measurement are preferable to the internal dial pattern, since readings are more convenient to take and the lighting of the dial is generally better. *When using cylinder dial gauges* it is the general practice to measure the differences or variations, expressed in $\frac{1}{1000}$ in. of the cylinder bore from the original standard diameter to where the cylinder gauge is set before insertion in the cylinder. For this purpose standard cylindrical rings, made to a high degree of precision and with hardened surfaces, are supplied in various sizes. The cylindrical dial gauge is placed with its measuring contacts inside the ring, and the zero of the gauge is then adjusted under the needle. Thus if the diameter of the hole in the standard ring is, say, 2·500 in., and the gauge is set to zero inside the ring hole, all subsequent gauge readings will show the differences in $\frac{1}{1000}$ in. of the cylinder barrel from this standard diameter. For worn cylinders the differences will be shown as positive readings on the dial gauge.

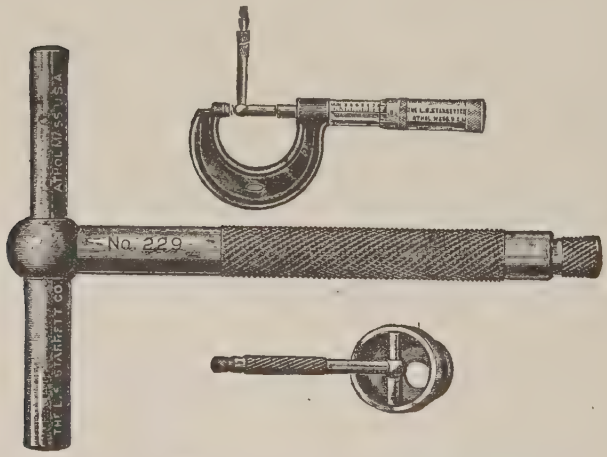


Fig. 49.—The Telescopic-type Gauge for Hole Measurements.

Telescopic Gauges

An inexpensive type of cylinder-measuring gauge is that known as a *telescopic gauge.* It requires the use of an outside micrometer gauge, but it is possible to measure the inside diameter of a hole very accurately so that shrink fits, bearing fits, or loose fits can be made and measured. Fig. 49 illustrates the Starrett telescoping gauge, which has a knurled holder and two measuring arms, one of which is a push fit in the other and can be locked in any position. To use this gauge for the purpose of measuring a hole, compress the telescoping head and lock the plunger by a slight turn of the knurled screw in the end of the handle, insert the head inside the hole, release the lock, and the plunger will expand across the hole to a fit. Now lock the plunger by a slight turn of the screw, withdraw, and calliper over the ends of the head with a micrometer (see upper illustration, Fig. 49), which will give the exact size of the hole. The ends of each telescope head are hardened and are made on a radius of the smallest hole it will enter. These instruments are more reliable than ordinary leg callipers on account of the tendency of the legs of the latter to spring and of the points to catch in blow holes or other depressions. They can be used, of course, either in fitting cylinders to holes or holes to cylinders.

These telescopic gauges are made in five patterns for measuring, respectively, from $\frac{1}{2}$ to $\frac{3}{4}$ in.; $\frac{3}{4}$ to $1\frac{1}{4}$ in.; $1\frac{1}{4}$ to $2\frac{1}{8}$ in.; $2\frac{1}{8}$ to $3\frac{1}{2}$ in., and $3\frac{1}{2}$ to 6 in.

Inside Micrometer Callipers

These *bar* micrometers (Fig. 50) consist of a set of standard-length gauge rods or bars—usually in 1-in. steps from 1 to 8 in.—and a micrometer head similar in principle to that of a micrometer calliper for measuring from 0 to 1 in. to an accuracy of $\frac{1}{1000}$ in. The extension rods are provided with a collar, against which the rods can be set accurately in the micrometer head.

It is important when setting these rods to see that the zero mark on the collar coincides with the zero mark on the micrometer head. An auxiliary handle is provided to hold the micrometer assembly; it is arranged to fit at right angles to the micrometer, on the side opposite the locking screw, which may be identified by its small groove.

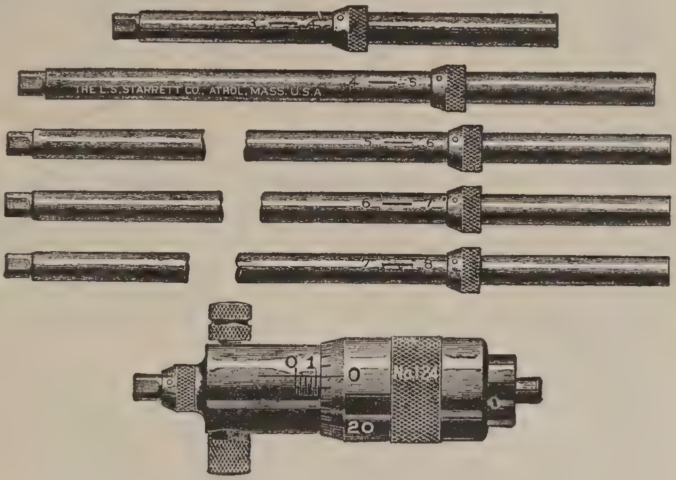


Fig. 50.—A Set of Bar Micrometer Rods and Micrometer Head.

Starrett Cylinder Gauge

Fig. 51 illustrates the Starrett cylinder gauge, introduced to facilitate the rapid measurement of cylinder wear or dimensions and also to enable internal-diameter measurements to be transferred to an outside micrometer in connection with piston measurements. The gauge shown is of robust construction, and consists of a dial indicator operated by a plunger rod or pointer; there is a fixed button-pointer on the back of the gauge; this is accurately made, hardened, and finished dead smooth. The dial, which has a non-breakable crystal, is mounted on a block which moves at right angles to the sled; the latter has two line contact points, which are at all times in alignment with the walls of the cylinder. The two contact points, which independently cause the indicating hand to travel over the dial, give a self-centring action.

The dial gives readings of one-thousandth inch divisions; by estimating between divisions it is possible to measure to about one five-thousandth of an inch.

Provision is made for measuring cylinders from 2½ in. to 6 in. diameter, two adjustable rods being provided for this purpose; these may be carried in the hollow handle of the gauge. The dial is graduated so as to show *plus* or *minus*, one whole turn of the hand being equivalent to ·1 in. By turning the knurled rim the dial may be moved instantly so as to bring the 0 mark to any desired position in relation to the hand.

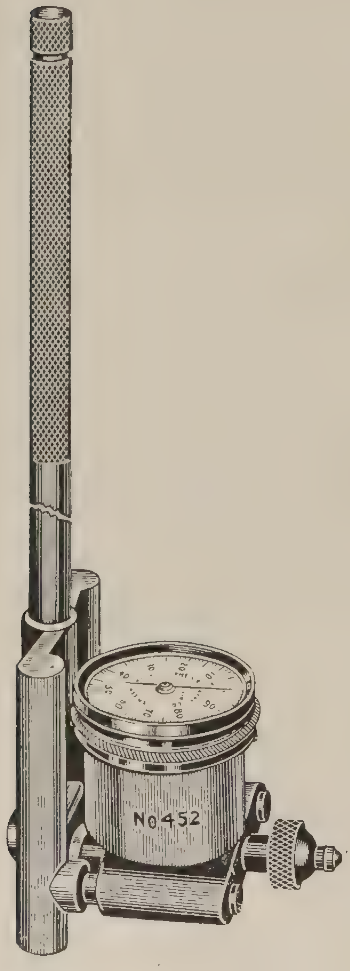


Fig. 51.—Starrett Cylinder Gauge.

The Ames Cylinder Gauge

A recent improvement in commercial cylinder gauges is that shown in Fig. 52. It consists of a rod, part of which is hexagonal in shape and one end of which is attached to a ground anvil. Another ground anvil and a series of accurately ground washers in various thicknesses are held on to the handle rod by means of the milled end screw shown. The removable anvil can be placed on the handle with washers of sufficient thickness ahead of it to increase the minimum distance of 2½ in. by sixteenths as desired.

This *setting-tool handle* is used to set the distance between the two measuring points A and B of the dial gauge member so that the initial or zero reading is known before the gauge is inserted in the cylinder to be measured.

Suppose for example it is known that the approximate bore of the cylinder—as given by a rule measurement—is 2¾ in. Then the two anvils C and D (Fig. 52) are set at this distance apart, by inserting the ¼-in. washer between the two anvils (which are normally 2½ in. apart).

The dial-gauge movable point is then adjusted so that when the gauge is placed between the anvil points the gauge itself reads zero; the gauge contacts are then exactly 2¾ in. apart.

If now the gauge is inserted in the cylinder, using the setting-tool handle, any variation of the cylinder bore from $2\frac{3}{4}$ in. will at once be shown by the movement of the needle. If the bore is smaller than $2\frac{3}{4}$ in., the needle will move to the left, or negative side; if greater, to the right, or positive side. In this way it can readily be seen whether the bore is oval or tapered and whether it is ridged at the ends of the piston stroke. By estimating one-half divisions this gauge will read to $\frac{1}{2000}$ in. accurately.

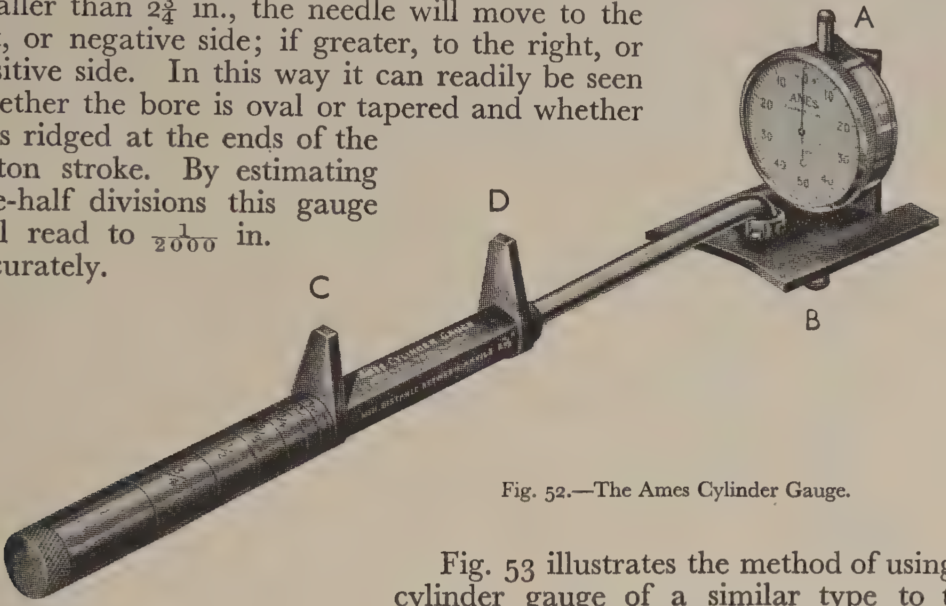


Fig. 52.—The Ames Cylinder Gauge.

Fig. 53 illustrates the method of using a cylinder gauge of a similar type to the Ames gauge by inserting it into the bore of the cylinder with the aid of the handle shown.

The only drawback to this type of cylinder gauge is that the reading dial moves into the cylinder block and is not so convenient or easy to read as in the case of cylinder gauges of the outside dial pattern, such as the Mercer gauge shown in Fig. 55. A strong illumination is necessary for inside-reading-type cylinder gauges.

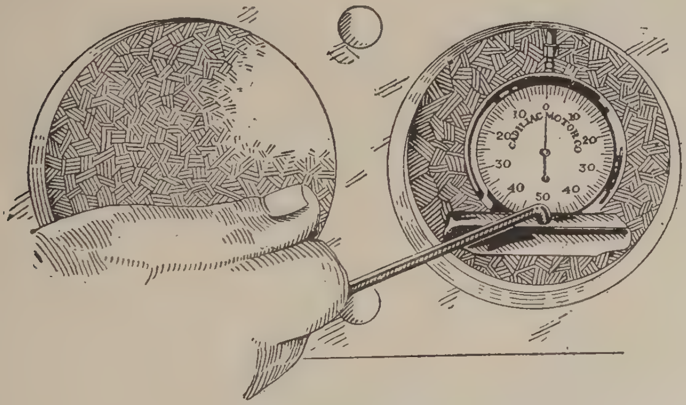


Fig. 53.—Method of using Ames-type Cylinder Gauge.

Fig. 54 illustrates another form of cylinder gauge of the direct-reading pattern. It consists of a vertical tubular portion at the upper end of which is mounted a gauge reading in thousandths of an inch, and at the lower end a T-shaped fitting, with contact ridges formed on the outer ends of the arms. The foot of the T contains the measuring contacts or plunger. When the T-piece is inserted into the cylinder to be measured it makes contact at three places, namely, the two ridges on the arms and the end of the feeler. The latter in direct contact with a curved connecting link (as shown in the upper inset diagram, Fig. 54) which in turn makes contact with the rod passing through the vertical tube to the indicator dial above. The feeler (on the left in Fig. 54) transmits its movement to the vertical rod through the curved link shown, and thence to the dial hand. There is a spring control, so that no backlash can occur. It will be seen that on rocking the instrument from one side to the other within the cylinder the readings will alter according to the angle at which it is held. There is only one position, namely when all three points of contact lie on the true circumference of the cylinder, which corresponds to the minimum dial reading observed.

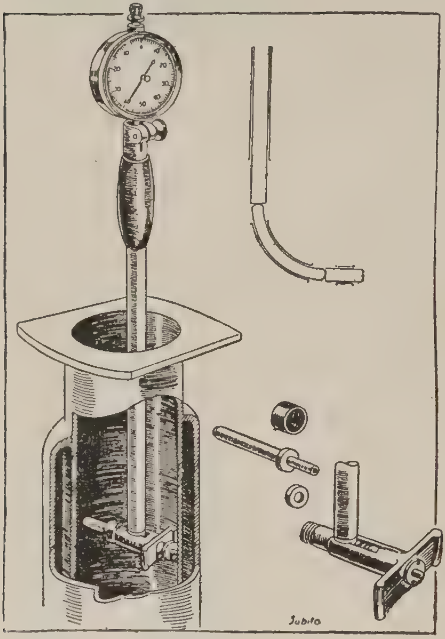


Fig. 54.—The " Subito " Gauge (Internal).

The gauge illustrated is provided with feelers of various lengths to suit cylinders of different diameters; it is made in six different sizes covering a range of diameters from 20 mm. to 400 mm. (i.e. ·787 in. to 15·748 in.).

The gauge shown is known as the " Subito."

An external form of micro-gauge made by the same firm has an adjustable plunger, and a spring-controlled measuring one, connected through a curved contact piece to a horizontal plunger of the measuring dial. This outside micro-gauge is so designed that it can be used for bench purposes as a stand gauge. In both gauges described the dial can be rotated to alter the position of the zero relatively to the hand. The adjustable end of the outside gauge is set by standard block gauges with the dial reading at zero. The instrument is made in three sizes, namely from 0 to 60 mm., 60 mm. to 100 mm., and 100 mm. to 160 mm.

The Mercer Cylinder Gauge

This cylinder gauge[1] employs a dial type of indicator which is always well outside the cylinder to be measured, so that variations in the cylinder bore can readily be observed. It consists of a bar type of gauge member which is inserted in the cylinder, and an extension arm or shank, carrying at its other end the dial gauge. The latter is graduated in divisions of half-thousandths of an inch, and it is possible to estimate accurately to half divisions, i.e. to quarter-thousandths of an inch. The gauge is also supplied for measuring in divisions of hundredths of a millimetre.

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[1] J. E. Baty & Co., Ltd., London, S.W.1.

In use, the gauge is placed square in the cylinder and is then rocked slowly to and fro—as shown by the arrows in Fig. 55. The maximum reading of the indicator is taken as the true reading of the bore.

It is necessary to calibrate the gauge with an outside micrometer, or a ring of known internal diameter, in order to obtain absolute measurements, but differences in cylinder-bore sizes can be read off directly to quarter-thousandths of an inch.

The Mercer internal gauge is made in different sizes, including a small model with a measuring range of $\frac{7}{8}$–2 in. The model used for the measurement of automobile cylinders has a range of 2–6 in., and, as stated, it is possible to take readings to within ·00025 in. with these gauges.

Another type of internal measurement instrument, known as the Mercer crankshaft gauge, is of the dial-gauge type, and is employed for measuring the alignment of crankshaft bearings.

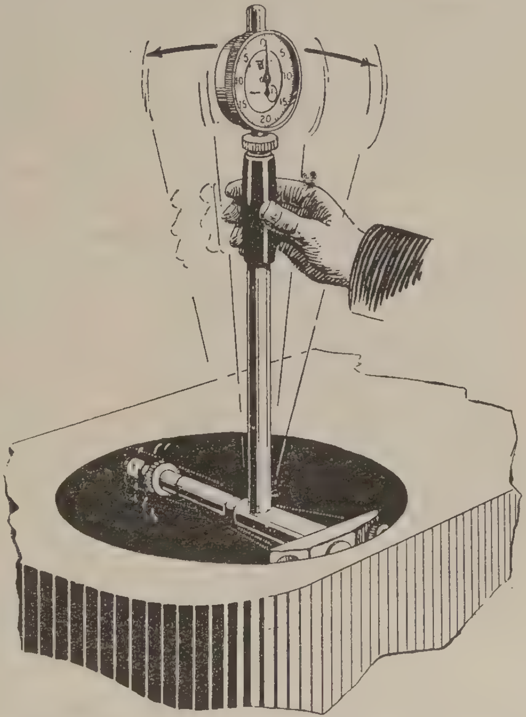


Fig. 55.—The Mercer Cylinder Gauge, shown measuring Cylinder Bore.

Notes on Cylinder Gauges

In connection with the design and use of cylinder-measuring devices, it is important that the gauge should be held so as to measure *normal* to the axis; if it is held in an inclined position the reading given will be incorrect, being *greater* than the true diametral measurement.

When measuring the diameter of a cylinder of an engine which has been in use for some time, see that the gauge is inserted in the working part of the cylinder, as there is usually a slight ridge formed at the extreme ends, due to wear of the cylinder barrel. Further, the diameter where the piston thrust is greatest (i.e. near the top on the down-stroke) is usually greater, due to increased wear, than elsewhere, thus giving an out-of-round section. The diameter should be measured at several places along the cylinder barrel.

Finally, before measuring make sure that the cylinder is quite clean, i.e. free from oil and dirt.

It is advisable when taking measurements of worn cylinder barrels to measure the distance from the machined face of the cylinder block to the gauge contacts and to write down the gauge readings and their distances from the machined face. If it is borne in mind—as is explained in fuller detail in Chapter 1—that automobile cylinders not only wear taper but also oval, and that there is an unworn ridge above the piston top land position, this will be a useful guide when making measurements. Further, it should be mentioned that the maximum amount of wear generally occurs at just about the top centre position of the upper piston ring, so that special care should be exercised to take measurements there.

The mechanic using dial-pattern measuring instruments should remember that these contain delicate mechanisms that may easily be damaged if dropped or knocked severely, thereby affecting their accuracy and reliability. Such gauges must be treated with the same care as watches, and always kept in their cases when not in actual use.

To obviate risk of damage, it is a good plan to keep dial gauges in the stores and to issue them for limited periods to operators, the gauges being returned to store when not in use.

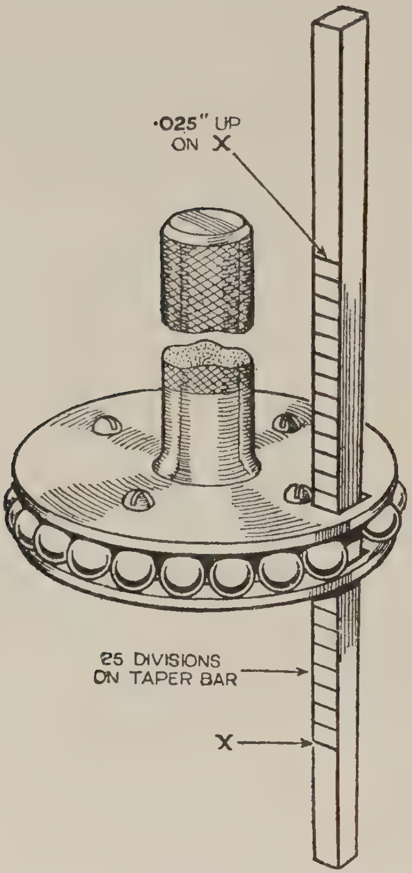


Fig. 56.—A Simple Form of Cylinder Gauge.

A Simple Cylinder Gauge

A novel design of cylinder-bore gauge that does not depend upon the use of a dial gauge yet enables readings to be obtained quickly and accurately is illustrated in Fig. 56.[1] It consists of an upper and lower circular disc forming a kind of ball-race or container for a ring of ball bearings which are free to move to a limited extent in their container. A rectangular hole is arranged through each of the circular discs, and a graduated tapered steel bar, also of rectangular section, can pass through the hole in question. The method of using this gauge is to insert the ball container in the cylinder and then press the tapered rod down until the balls make contact with the cylinder wall. The graduation on the bar opposite the top of the upper circular disc is then noted and, by reference to a table or calibration chart, the absolute reading, i.e. the actual cylinder diameter, can be read off. The graduated bar has 25 equal divisions,

[1] W. J. Morrison, *Motor Transport.*

each corresponding to a diameter difference of ·001 in., so that the total range of measurement of the bar amounts to ·025 in. This covers the usual limits of cylinder wear of automobile engines.

Crankshaft Gauge

Fig. 57 illustrates the Ames crankshaft gauge which has been designed for the purpose of testing the main bearings and crank-pins of crankshafts to show whether these are tapered or out-of-round. It also measures the diameter of round parts quickly and accurately.

It consists of a fixed member having a knurled handle, a graduated scale, and an upper contact pin. The other movable member has a pair of V-blocks, or plates, which, when the instrument is in use, is in contact with the shaft to be measured, thus ensuring that the instrument is "square." This V-block member can slide in a diametrical direction, being constrained by means of compression springs to make contact with the shaft to be measured. The measuring point of the dial gauge is located in the centre of the V-block and is directly in line with the upper contact.

The stem of the gauge is divided into one-tenth-inch divisions, as in the case of ordinary micrometers, whilst the dial gauge is graduated in $\frac{1}{1000}$-in. divisions, there being 100 of these divisions around the dial, thus making $\frac{1}{10}$ in. in all. The whole numbers on the stem represent the total number of tenths, and the dial readings give the $\frac{1}{100}$ and $\frac{1}{1000}$ in. additions.

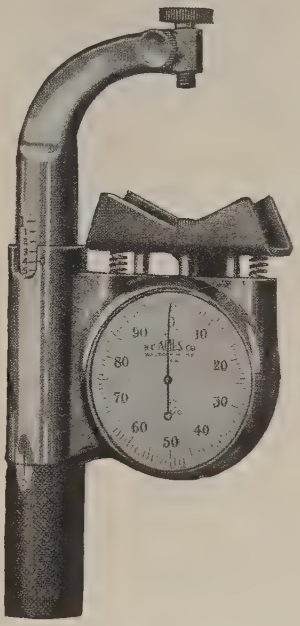


Fig. 57.—The Ames Crankshaft Gauge.

After removing worn bearings from the crankshaft and cleaning the shaft, the Ames gauge can be applied with the crankshaft in position, only a few seconds being necessary to make a complete check of the parallelism and roundness of the shaft. The gauge is made in two sizes, viz. No. 1 from 1 in. to $2\frac{1}{4}$ in., and No. 2 from 2 to $3\frac{1}{4}$ in., respectively.

The Churchill "Automike" Gauge

A special design of dial gauge used for precision checking of grinding diameters during actual operations is shown in Fig. 58. It has a convenient handle for holding and applying the gauge, and a V-jaw which is brought into contact squarely with the cylindrical work. The wearing surfaces and gauging point are hardened to resist wear.

The gauge is set to a master cylinder, the needle of the dial gauge being set to zero by rotating the milled nut shown. When applied to the work the gauge shows by how much the diameter of the work differs from the standard value; or it may be set to the final ground diameter, using a comparison shaft for the purpose.

The gauge will show out-of-roundness and taper effect in the work whilst it is being ground.

The gauge covers a range of $1\frac{1}{2}$–$2\frac{3}{4}$ in. of work diameters, and each wide division of the dial represents ·001 in.; it is not difficult to estimate to decimal parts of a division, and thus obtain a higher degree of measuring accuracy.

It is particularly useful for checking crankshaft journals during grinding operations.

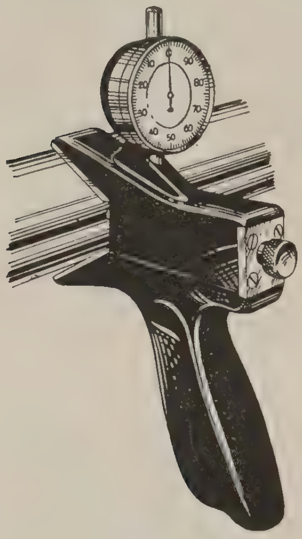


Fig. 58.—The Churchill "Automike" Gauge.

Screw-thread Gauges

It is frequently necessary to identify screw-thread pitches in connection with motor repairs and replacements to ensure that nut members will fit their bolt counterparts or for rethreading purposes.

The usual method of ascertaining the pitch of a screw thread is to place a steel rule over the tops of the threads and then count the number of crests of the threads per inch of the rule scale. This is a somewhat tedious and not always reliable method. For this reason it is advisable to employ one of the available makes of screw-thread gauges now available for the purpose. Not only is a good deal of time saved by the use of such gauges, but there need be no doubt as to the accuracy of the thread pitches measured.

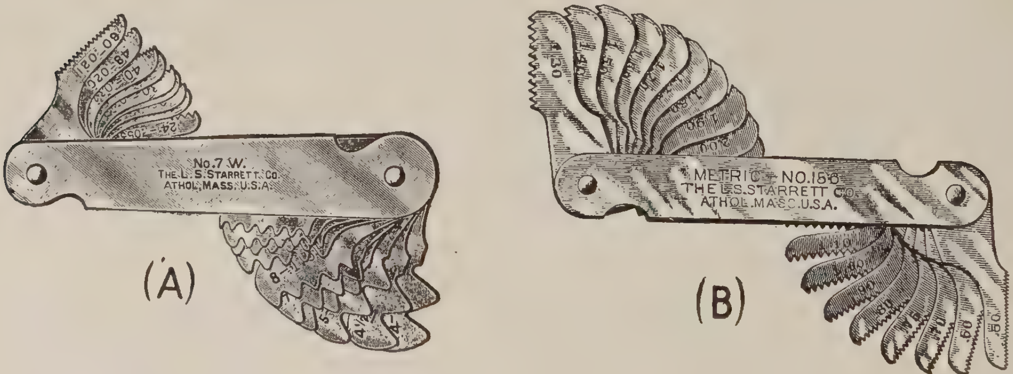

No.7 W.
THE L.S.STARRETT CO.
ATHOL, MASS. U.S.A.
(A)
METRIC NO.156
THE L.S.STARRETT CO.
ATHOL.MASS.U.S.A.
(B)

Fig. 59.—Screw-thread Pitch Gauges; (A) English, (B) U.S. and Continental (Metric).

Fig. 59 (A) illustrates the Starrett screw-pitch gauge for Whitworth screw threads. It is made similarly to the feeler gauge, namely with a number of blades which can hinge around pins in the end cover plates.

The model shown in Fig. 59 (A) has 26 pitch blades covering all Whitworth threads from 4 threads per inch to 60 threads per inch.

Occasionally, when American or Continental vehicles have to be serviced, there may be some doubt as to the type and pitch of the screw threads used, so that it is advisable to have a screw-pitch gauge to suit these threads. The latter belong to the 60° truncated V-thread class, and their pitches are expressed in millimetres. A typical gauge is shown in Fig. 59 (B), and it contains 28 pitch blades cut with threads of pitches from ¼ mm. up to 2½ mm. in small steps.

The pitches of the threads are stamped clearly on the corresponding blades, so that by testing the various blades against the screw thread to be identified it is easy to find the one that fits exactly.

Another design of screw-thread gauge which is both easy and quick to use is the Helix screw-pitch indicator, which is illustrated in Fig. 60. It consists of a plate having a number of V-grooves, which not only radiate from one end but also increase in width and depth according to a linear rate. There are seven whole threads in all, and with the divergence or angle employed these cover a range of Whitworth screw threads from 8 threads per inch to 48 threads per inch. It is only necessary to clean the screw member to be measured and then move it along the gauge until it fits into the grooves, when the number of threads per inch can be read off from the scale on the left-hand side.

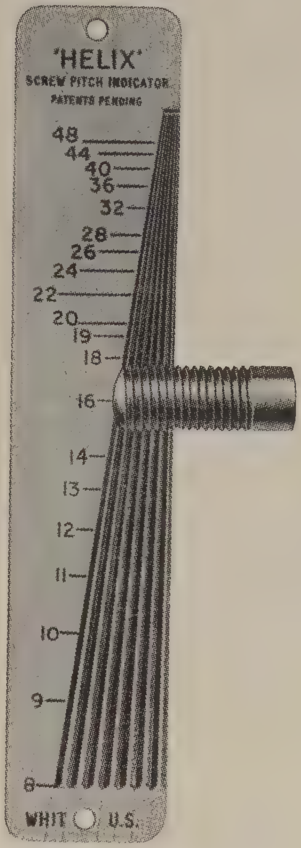


Fig. 60.—The Helix Screw-pitch Gauge.

CHAPTER 4

DISMANTLING THE ENGINE

One of the most frequently recurring jobs which the garage engineer has to undertake is the dismantling of part, or all, of the engine of a motor vehicle for general overhaul or repair—as the case may be. Before proceeding to give an account of the more common methods of dismantling an engine it may perhaps be of interest to consider the general signs or symptoms which reveal the necessity for such overhauls. The owner-driver, and those who possess vehicles which have been in use for an appreciable period, are sometimes uncertain as to the correct time in the life of the engine at which to commence overhauling; it is to these users in particular that our remarks are intended to apply.

When should an Engine be Overhauled?

Leaving aside the question of accidents and significant breakages due to mechanical defects or persistent misuse, and assuming the engine is capable of working or, rather, of functioning in the ordinary sense, there are certain definite symptoms which at once indicate to the trained mind that a thorough overhaul is needed. Perhaps the most frequent example which comes before our notice is that of the car which has been used since new by a single owner. For the first 2,000–4,000 miles or so the engine will, if properly lubricated and adjusted, show a small progressive, or slight increase in, power output (due to the bearing surfaces of the pistons, rings, cylinders, and bearings having become well bedded-in and polished). After this, if the engine is not decarbonised, there may be found a slight falling-off in performance, as for example when climbing hills or accelerating, accompanied by a tendency on the part of the engine to " knock " when working on full throttle opening. After long periods, the engine will show signs of overheating on stiff hills, the water boiling, and some smoke coming from the breather and crankcase; this effect is accentuated in hot weather.

Occasionally, when accelerating or working at full throttle, there may be a misfire or two.

These symptoms point to the usual results of normal running for appreciable periods, namely, formation of carbonaceous deposit on the walls of the combustion chamber, piston crown, and valve heads; the carbon acts as a non-conductor of heat, thereby raising the working temperature of the cylinder. If much carbon deposit has formed there is a risk of pre-ignition, due to the fact that at one part of the combustion chamber —usually where there is a projection—the carbon is heated to incandescence by the exploding gases, and being unable to conduct the heat away with sufficient rapidity remains in a glowing condition during the ensuing exhaust and compression stroke. The mixture being compressed is, therefore, prematurely ignited, and the explosion takes place before the piston has reached the top of its compression stroke. Each subsequent ignition, by this means, occurs earlier and earlier, until the engine refuses to operate and stops.

If carbon deposit (principally from the lubrication oil) has been formed, due to leaky piston rings or persistent over-oiling, a kind of tarry deposit is liable to occur on the valve stems—more particularly in the case of the hotter exhaust valve—and in time this will cause the valve to stick up—that is, to remain open after the operating cam has moved past the closing position; the result in the case of a multi-cylindered engine is a series of misfires; sometimes, however, the valve only sticks up occasionally, at small throttle openings.

Compression Loss.—Another symptom of overhaul necessity is a general loss of compression when the engine is hot. In this respect, if the engine is slowly cranked by hand with the ignition switched off the compression can readily be "felt" and compared with its state when the engine was new or just "run in."

It is important to check the compression of each cylinder in turn when the engine is at its normal operating temperature, the reasons for this being: (1) that the lubricating oil is thicker, or more viscous, when cold than when hot, so that there will be a much greater resistance to cranking over by hand, and this may mask the compression effect; (2) there are certain differences in the expansions of the aluminium-alloy pistons, their rings, and the cylinder material, which may result in a difference in fit when cold but not in the heated condition. When testing the compression by the hand cranking method it is advisable to turn the starting handle slowly, noting how long the compression of each cylinder, in turn, can be "felt" before it leaks away: the longer the compression is sustained the better is the condition of the piston, rings, and cylinder walls.

Apart from the pre-ignition or detonation knock, each of which is a distinct phenomenon, although both are apt to be caused by excessive carbon deposit, the following are additional signs of an engine requiring overhaul.

Inability to Run Slowly.—Engines, which in their normal condition would run fairly slowly, often refuse to do so after being in use for some appreciable time. Loss of compression, leaky valve seatings, worn valve stems, burnt-away sparking-plug electrodes, mixture leakage, bad carburation, and other causes contribute to this result.

Gummed Piston Rings.—Another cause of compression loss is that of piston rings which, owing to an accumulation of gummy matter from the lubricating oil, have become wedged in their grooves. Over-lubrication and the use of unsuitable oils which leave a gummy deposit when exposed at the temperature of the exploding gases are the causes of this trouble. In most cases the rings are gummed up in their closed position, so that there is an appreciable amount of blow-back past them. Compound piston rings are rather more prone to gumming troubles.

Periodic Mechanical Knocks.—Apart from what may be termed " combustion " knocks, such as " pinking " or detonation and pre-ignition, engines sometimes develop a regular " tapping " or mechanical knock. This may be due to excessive clearance between the valve-operating tappet and the valve stem (or valve rocking arm and valve stem in the case of overhead valves), a defect which may readily be checked by measuring the clearances between the valves and tappets. Another subsidiary cause is that of slack, or *backlash, in the timing gears* or secondary-shaft drive. In the case of chain-driven camshafts and pump or magneto shafts, stretch of the chain may become sufficiently great for the chain to hit against the timing-gear casing; more particularly is this apt to occur when the engine is idling, or when the engine is being helped or driven by the forward motion of the car, as when descending a hill with the clutch and one of the gears engaged. The transmission then tends to drive the engine, and the latter sometimes tries to drive the transmission, so that there may be a kind of reversal of motion in the worn bearings or " backlash," which is accentuated under these conditions, and is evident by increased noisiness.

Another frequent (and sometimes baffling) cause of engine noise was that of the fan belt—when flat belts with metal fasteners were employed. Once every revolution of the belt the fastener knocks against some metallic part of the engine or belt pulley, and this gives rise to a regular periodic noise. In a few instances the fan blades themselves, due to bending, have been found to just flick against some engine part or the radiator and to cause a regular knock.

Locating Connecting-rod-bearing Knocks

The most serious source of mechanical knock, and one which we have left until the last, is that caused by wear in a big-end bearing of one of the connecting rods. This type of knock is characterised by an unmistakable *thumping noise* occurring at engine speed, and more pronounced when the engine is labouring, as, for example, when endeavouring to climb a stiff hill on top gear. This kind of knock can be distinguished from ignition or weak-mixture knock by retarding the ignition and enriching the mixture, when the latter should disappear.

Excessive wear in the gudgeon pins will also cause a knock, but this is usually of higher pitch than a big-end knock, and fairly persistent under all running conditions.

Another method of testing an engine for worn big- or small-end bearings is to run the engine in neutral, slowly, and to "short" each of the sparking plugs in turn with, say, a screw-driver. If any connecting-rod bearing is worn the knock will disappear when its cylinder is shorted.

To ascertain whether the piston (gudgeon) pin is loose in the piston, or small end of the connecting rod, short the sparking plug of each cylinder in turn and listen by placing a wooden rod or stethoscope against *the top of the cylinder or water jacket.* The knock will be much louder than that heard when the wooden rod or stethoscope is held against the *crankcase.*

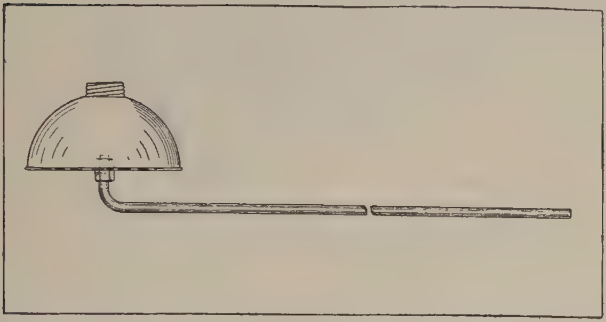


Fig. 61.—A Simple Home-made Stethoscope, utilising an old Oil-can as a Sound Amplifier.

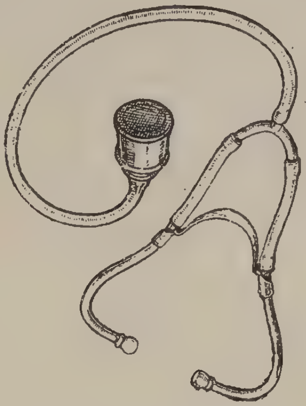


Fig. 62.—A Motor Stethoscope.

It is usually more difficult to distinguish the knock due to wear in the main bearings; unless the wear is excessive, this cannot be located by merely rocking the crankshaft endwise. It is generally necessary to remove the oil sump and test the adjustment direct.

If an engine with worn big-end bearings be speeded up for a short time with the gear lever in neutral, the presence of wear can usually be detected by listening intently to its running sounds. The use of a *stethoscope*, such as that employed by medical men, is of much assistance in this respect. Special engine-knock diagnosing stethoscopes are now sold by motor accessory firms and others for this purpose.

Fig. 62 shows a form of stethoscope designed expressly for the motor mechanic's use. It is provided with the usual two ear-pieces of the medical stethoscope, and a "microphone" end which is held against different parts of the engine in order to detect such faults as worn big-ends, little-ends, slack pistons, noisy gears, etc., by listening to the magnified sounds of the engine.

The "Bin-Aural" instruments (Fig. 63) for testing machinery are more elaborate and yield accurate results. The principle employed is to compare any unknown noise heard in the engine or machine with a standard noise. So delicate is the system that an operator can detect minute differences between the sounds, and also measure these differences. In operation the Sonometer, as it is termed, may be regarded as being similar to a bridge test of electrical resistance—that is, on one side there is either the standard unit, or the electrical standard, and on the other side there is the part under test, the position of the dials required to effect a balance between the sounds giving the difference or value.

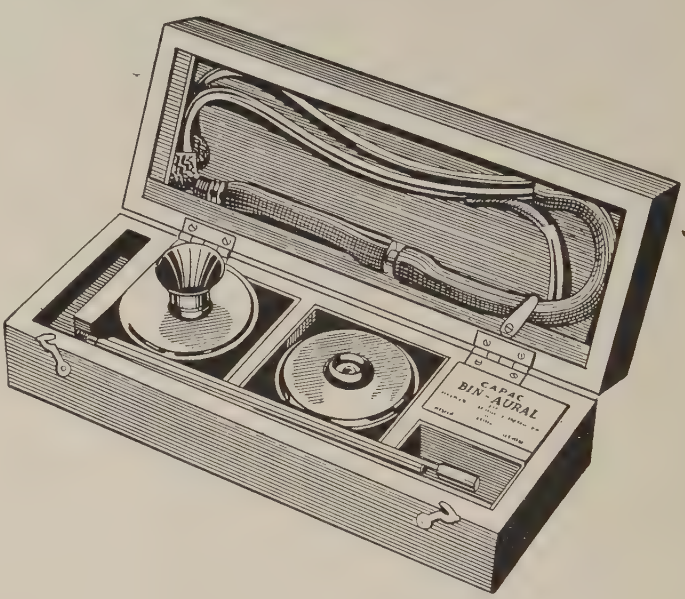
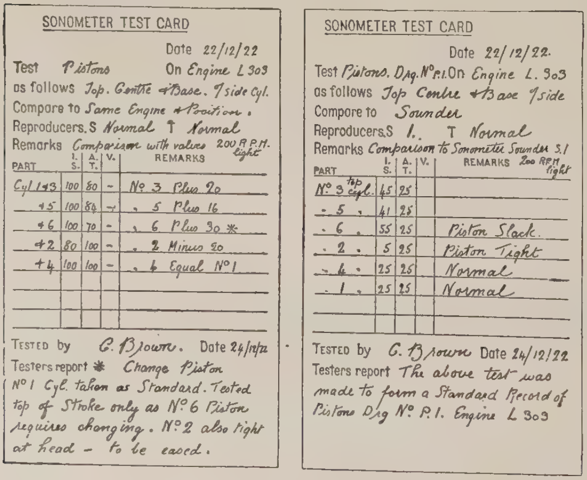


Fig. 63.—The "Bin-Aural" Outfit, for Testing Knocking in Engines, etc.



SONOMETER TEST CARD

Date 22/12/22
Test *Pistons* On *Engine L 303*
as follows *Top. Centre & Base. T/side Cyl.*
Compare to *Same Engine & Position.*
Reproducers. S *Normal* T *Normal*
Remarks *Comparison with values 200 R.P.M. light*

PART	I. S.	A. T.	V.	REMARKS
Cyl 1+3	*100*	*80*	-	*No 3 Plus 20*
+5	*100*	*84*	-	*„ 5 Plus 16*
+6	*100*	*70*	-	*„ 6 Plus 30 ✱*
+2	*80*	*100*	-	*„ 2 Minus 20*
+4	*100*	*100*	-	*„ 4 Equal No 1*

Tested by *C. Brown.* Date *24/12/22*
Testers report *✱ Change Piston*
No 1 Cyl. taken as Standard. Tested top of Stroke only as No 6 Piston requires changing. No 2 also tight at head – to be eased.

SONOMETER TEST CARD

Date *22/12/22.*
Test *Pistons. Drg. No P.1.* On *Engine L. 303*
as follows *Top Centre & Base T/side*
Compare to *Sounder*
Reproducers. S *1.* T *Normal*
Remarks *Comparison to Sonometer Sounder S.1 200 RPM light*

PART	I. S.	A. T.	V.	REMARKS
No 3 top cyl.	*45*	*25*		
„ 5 „	*41*	*25*		
„ 6 „	*55*	*25*		*Piston Slack.*
„ 2 „	*5*	*25*		*Piston Tight*
„ 4 „	*25*	*25*		*Normal*
„ 1 „	*25*	*25*		*Normal*

Tested by *C. Brown* Date *24/12/22*
Testers report *The above test was made to form a Standard Record of Pistons Drg No. P.1. Engine L 303*

Fig. 64.—A Typical Test Card.

The system used for recording the results of either comparison or value tests is illustrated on the test cards reproduced (Fig. 64); no specially trained operators are necessary with this device.

A more elaborate type of noise-locating and measuring apparatus, which is suitable not only for engine sounds but also those of gearboxes, back axles, exhausts from silencers, etc., is the Western Electric sound meter. The method employed is an electrical one, and it is independent of the operator, who has only to read the sound intensity as a deflection on the meter scale. It is equally suitable for noises of short as well as of long duration, and requires no skill or previous experience on the operator's part.

Excessive Oil and Fuel Consumption

Another sign of engine wear, or need of an overhaul, is that of excessive oil and petrol consumption. In the former respect the manufacturers usually state what should be the ordinary oil consumption. Thus an engine of 12-h.p. rating will, during the first few thousand miles of its life, show an oil consumption of 1,500 to 2,000 miles per gallon, whereas a well-worn engine may show only about 400 to 600 miles per gallon of oil used. It is assumed in each case that the proper grade of oil is used and that the oil sump is kept replenished to the correct level.

This excessive loss of oil is due to leakages past the worn pistons and rings, main bearings, valve tappets, and sometimes joints in the crankcase; the former is the most frequent source of oil wastage, for the oil which gets past the pistons is burnt with the mixture and mostly forms carbon deposit and tarry matter on the valve stems. Regarding the excessive fuel-consumption factor, it is well known from scientific tests that a fairly rich mixture gives a higher average explosion pressure, and therefore greater power output, than a normal or weak petrol-air mixture, and in this respect when engines lose power for any reason they are often run on richer mixtures than normally, by a suitable carburettor or air-control manipulation.

Apart from this, there is the important fact that a worn and badly carbonised engine works less efficiently from the heat utilisation, or thermodynamic, point of view. An engine which is thermodynamically inefficient will not extract so much useful energy (or power) from its fuel, or, in other words, will use more fuel to develop a given power; loss of compression will cause a loss of efficiency with a consequent increased fuel consumption.

Again, leaky pistons tend to promote crankcase dilution of the lubricating oil by the escaping fuel from the mixture which gets past the rings. Not only is this manifested by increased fuel consumption, but the oil loses part of its lubricating value.

Modern car engines now incorporate *oil purifiers* or filters. In most cases, the hot engine oil is passed through a felt element or a series of special filter cloths or plates in a special chamber. These trap all matter of a sedimentary nature, but allow the clean oil to pass through. The whole of the oil is passed through the filter every few minutes, when the engine is working at a speed corresponding to 20 m.p.h., so that the cleansing process is very effective. It has been shown by means of a series of careful tests that after a car fitted with this type of filter has been run for 25,000 miles there is no more total abrasive sediment than in the case of a car engine not fitted with the filter which has run for 1,000 miles—in other words, the filter-fitted engine, so far as the abrasive or wearing material is concerned, should last about twenty-five times as long; there are, of course, other sources of wear than the above, and the actual useful life would be much shorter than that for this one factor alone.

Recapitulating the various signs and symptoms which give an indication of the fact that an engine requires overhauling, these can be enumerated as follows:

(1) Excessive carbon deposit, causing knocking and overheating.
(2) General loss of engine compression.
(3) Inability to run slowly.
(4) Periodical mechanical knocks.
(5) Excessive fuel and oil consumption.
(6) General falling off in hill climbing, acceleration, and top speed (or maximum engine revolutions).
(7) Increase in engine noise.
(8) Less smooth running.

Length of Service before Overhaul

It is very difficult to give exact information as to the road life, or length of service, before a motor-vehicle engine requires overhaul—so much depends upon the way in which the car has been maintained and operated.

Again, the useful life, before overhaul is necessitated, depends largely upon the actual design of engine, for there are both good and indifferent designs in service. The design of the pistons, the bearing pressures of the working surfaces, the lubrication system employed, lightness of the working parts, and similar factors, all influence considerably the life of an engine. Some earlier engines, for example, were designed with ample bearing surfaces and good materials, adequately lubricated; they also ran at medium speeds of, say, 2,000 to 2,500 r.p.m. Other high-speed engines obtain overall efficiency by sacrificing bearing areas and using higher running speeds; they therefore wear more rapidly.

Generally speaking, a well-designed medium-speed engine, apart from requiring decarbonising every 5,000 to 8,000 miles and valve regrinding at these same intervals, should not require a serious overhaul under 30,000 to 40,000 miles. On the other hand, some of the more expensive cars will run for 50,000 miles or more without apparently requiring a thorough engine overhaul. At the other extreme is the case of a badly designed or used car which may not run for more than 12,000 to 16,000 miles before it requires the engine dismantled. Incidentally, the life of a well-serviced car of good design is usually from 150,000 to 250,000 miles. Much greater mileages have been obtained from some cars and commercial vehicles.

Dismantling Procedure

In many cases, after it has been decided to dismantle the engine, it will not always be necessary to remove the engine bodily from the chassis, but only to take off the various accessories and fitments, cylinder head and undershield and crankcase sump, when the necessary parts, such as the valves, springs, pistons, and connecting rods, can be withdrawn.

On the other hand, from the garage engineer's point of view it may not be convenient to work on the engine whilst it is in the chassis, on account of space and accessibility considerations, so that he will often prefer to remove the complete engine unit and fix it on the special engine stand (described later). It is certainly better if much work has to be carried out to do this work in comparative comfort, and more expeditiously, by employing an engine stand. Moreover, if one has to overhaul a number of engines, it is better to do all of this work systematically, and in the most convenient manner and position in the works; in the latter respect the engine stand enables the mechanic to work on the engine in any part of the building, near his bench and tools, and in a good light; it saves him a number of journeys to and from the car.

Removing the Power Unit

The usual procedure to follow in removing the complete engine unit from a car is as follows: First, *run the water out* of the radiator and cylinder jackets. Remove the bonnet completely. Disconnect the *water pipes* from engine to radiator, taking care to mark each end and hose-clip so that each may be replaced correctly later.

It is also advisable to drain the engine sump of its oil before removing the engine from the chassis.

Disconnect next the *exhaust pipe*; frequently it will be necessary to release the silencer fixings from the chassis frame. Remove the *carburettor*, and, of course, its petrol supply pipe.

Disconnect the carburettor and ignition controls at the engine end.

Disconnect electric cables leading to the engine (dynamo) from the battery and switchboard, and from the starting motor to the starter switch. The ignition cables from magneto or coil to engine need not be disturbed.

Disconnect miscellaneous accessories, such as choke controls, primers, oil-pressure indicator (on dashboard), speedometer drive (in the case of combined engine-clutch-gearbox units), clutch, accelerator and brake pedals, etc. Disconnect the propeller-shaft universal coupling behind the gearbox. Finally, when all external attachments from other parts of the chassis, or body, to the engine are clear, take out the holding-down bolts on the crankcase and gearbox arms, when the power unit will be quite free to remove from the frame.

Removing Small Car Engine from Chassis

The method of removal of the engine unit from the chassis of the modern car differs appreciably from that employed in previous models, since both the chassis frame and bonnet are of different design. It will therefore be instructive to describe the removal of the engine and gearbox unit as a whole in the case of a modern and widely used small car, namely, the Austin A40. It is possible, however, to remove the engine separately from the gearbox, but the complete assembly is usually taken out of the chassis, and so will here be dealt with.

In general, the dismantling procedure outlined in the previous section is followed, but there are in addition certain special items of procedure which must be considered as follows:

After draining the radiator remove the split pin and washer from the fixed anchorage pin of the bonnet support (Fig. 65) located on the side of the heater compartment. On early models disconnect the snap connections to the horn leads at rear of bonnet. Before releasing the three bolts at each side of the bonnet, mark the bonnet along the edge of the hinge plates by means of a scriber; this will facilitate correct replacements. Remove the hinge bolts and lift away the bonnet.

Next, remove the radiator. The combined radiator supports and mudguard-wing tie bar should be left in position. The horns fitted on each side of the tie bar should be removed.

Working from above, uncouple the rubber connections of the heater pipes from the engine and turn back the left-hand pipe towards the scuttle, clear of the engine, remembering to remove the clip which holds the suction pipe of the ignition control to this pipe.

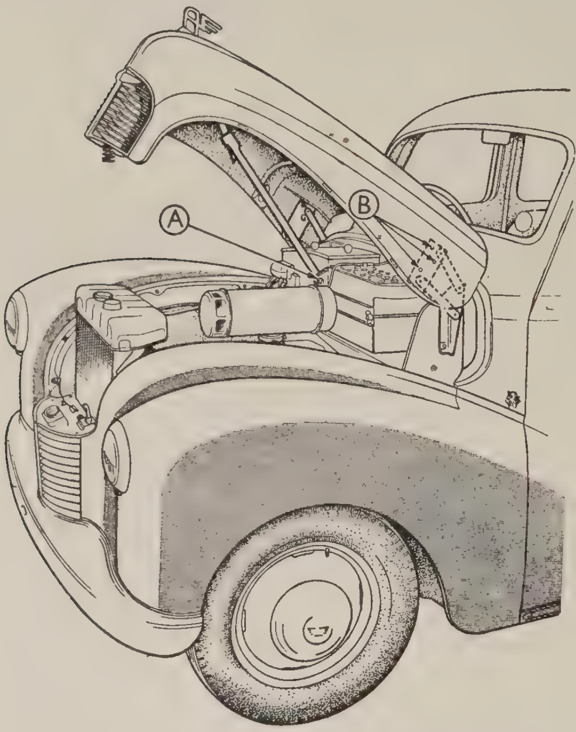


Fig. 65.—Showing Austin A40 Bonnet-securing Places.
A—Support Anchorage Pin. B—Hinge Bolts.

The air cleaner should now be removed followed by the valve-inspection cover. Disconnect the choke wire from the carburettor, followed by the throttle control arm and the flexible petrol pipe from the fuel tank to the petrol pump.

Disconnect the plug terminals, the low-tension coil lead from the distributor together with the high-tension lead from the coil, and remove the distributor cap. The flexible oil pipe which connects with the oil gauge should now be released, and a suitable plug inserted in the union now exposed; followed by the two terminals on the dynamo. Whilst still on this side, remove the top anchorage bolt from the starter flange and also the pull wire from the starter-switch lever on early models.

Still operating from above, remove three nuts and bolts holding the gearbox to the engine back plate. This will also release the earth-wire clip on the left-hand side of the engine and the clip of the heavy-duty cable to the starter on the right-hand side.

The car should now be raised at the front by means of a heavy-duty garage jack, placing wooden trestles under the front wheels as a safety precaution. It is advisable to place a wooden block between the jack head and the front frame member.

Here it is necessary to mention that it is advisable to *drain the oil* from the engine and gearbox before proceeding further. The fume extractor pipe must also be disconnected.

Next it is essential to *remove the gearbox cover* complete with the change-speed lever, in order to allow the engine and gearbox to be taken out of the chassis. Six bolts should be released to allow the gearbox cover to be removed; cover the exposed gearbox with a clean cloth to prevent ingress of dust. The speedometer drive is now disconnected from the gearbox.

At this stage it is advisable to consider the means for lifting the engine unit once it is released from the chassis frame. Fig. 66 shows the type of *engine lifting bracket* recommended by the manufacturer for this purpose. The angle should be of $\frac{3}{8}$- to $\frac{1}{4}$-in. thickness and of any convenient flange widths. The two high-tensile bolts for the stirrup member should be $\frac{1}{2}$-in. diameter. It will be observed that two sets of holes are provided for the solid loop. The central position is for lifting the engine only; if—as in the present case—the combined engine and gearbox unit is to be removed, the two rear holes should be used. The whole car should be lifted by means of a ramp or heavy-duty garage jack to facilitate underneath operations. Wooden trestles, or axle-stand units, may be used under each wheel member to keep the car in the raised position to enable the propeller shaft to be disconnected at the front universal joint.

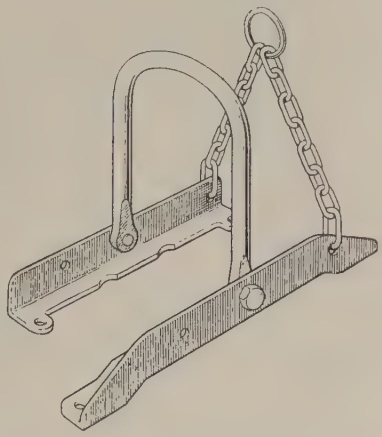


Fig. 66.—The Special Engine Lifting Bracket. The Chain is used for the Angular Lift and the Solid Stirrup for the Vertical Lift.

The clutch-pedal adjusting rod should now be disconnected.

Next, place a suitable support under the engine. On later models remove two bolts and nuts from the right and one nut and bolt from the left of the bracket of the rear adjustable stabiliser mounting of the gearbox, which is anchored to each side of the chassis. Follow this by the gearbox main mountings which are held each side by two bolts.

Release the engine front mountings by removing the four bolts each

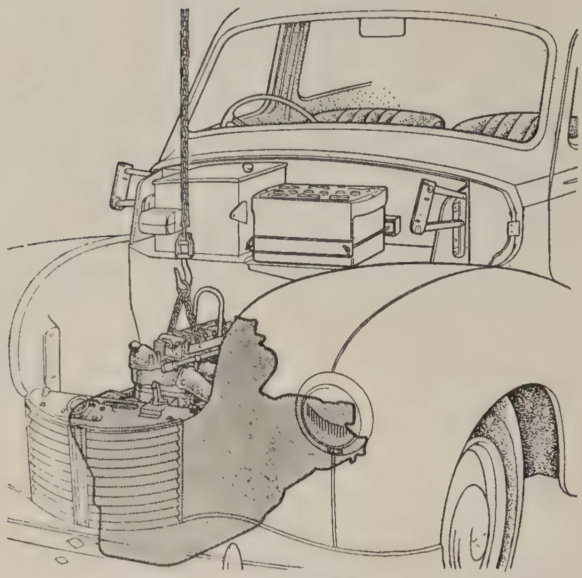


Fig. 67.—Showing the Lifting Tackle attached to the Chain Ring ready for Lifting.

side holding the mountings to the chassis frame. Then take away the support from under the sump, having previously attached the lifting bracket to the engine cylinder head at the four places indicated. The holes in the horizontal flanges of the angle-plate members are $12\frac{7}{8}$ in. apart, the holes being of $\frac{7}{16}$-in. diameter.

The lifting procedure is illustrated in Figs. 67 and 68. The cylinder block at the rear of the engine first comes into contact with the scuttle, so temporarily wedging itself. The lifting tackle is then attached to the ring at the forward end of the bracket; this gives the correct lifting angle to the unit as it is raised from the chassis. Gradually take the weight with the tackle, at the same time controlling the gearbox rear end. When clear of the scuttle lift the complete unit away from the car. Refitting of the engine is the reversal of the procedure described.

Removing Standard Vanguard Engine

The various engine-connected components, including those of the cooling system, radiator, petrol, exhaust system, etc., are removed after taking away the bonnet assembly. The procedure is then as follows:

Detach propeller shaft from gearbox flange by removing four bolts and Simmonds self-locking nuts.

Disconnect speedometer cable from gearbox by unscrewing knurled collar.

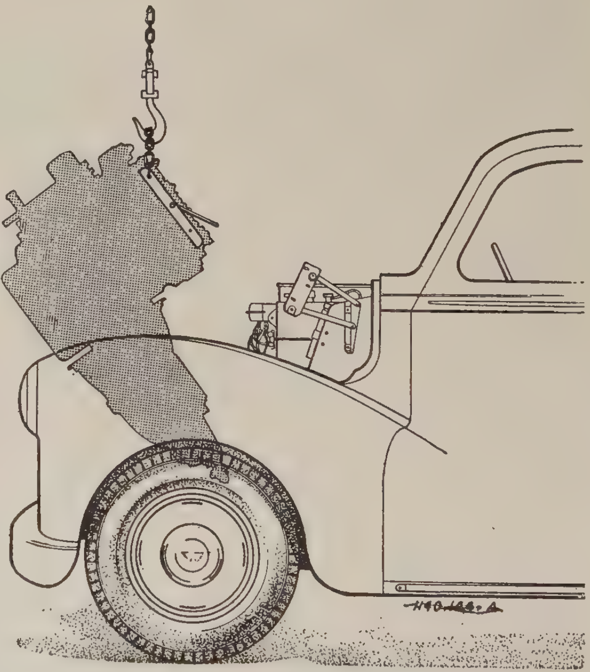
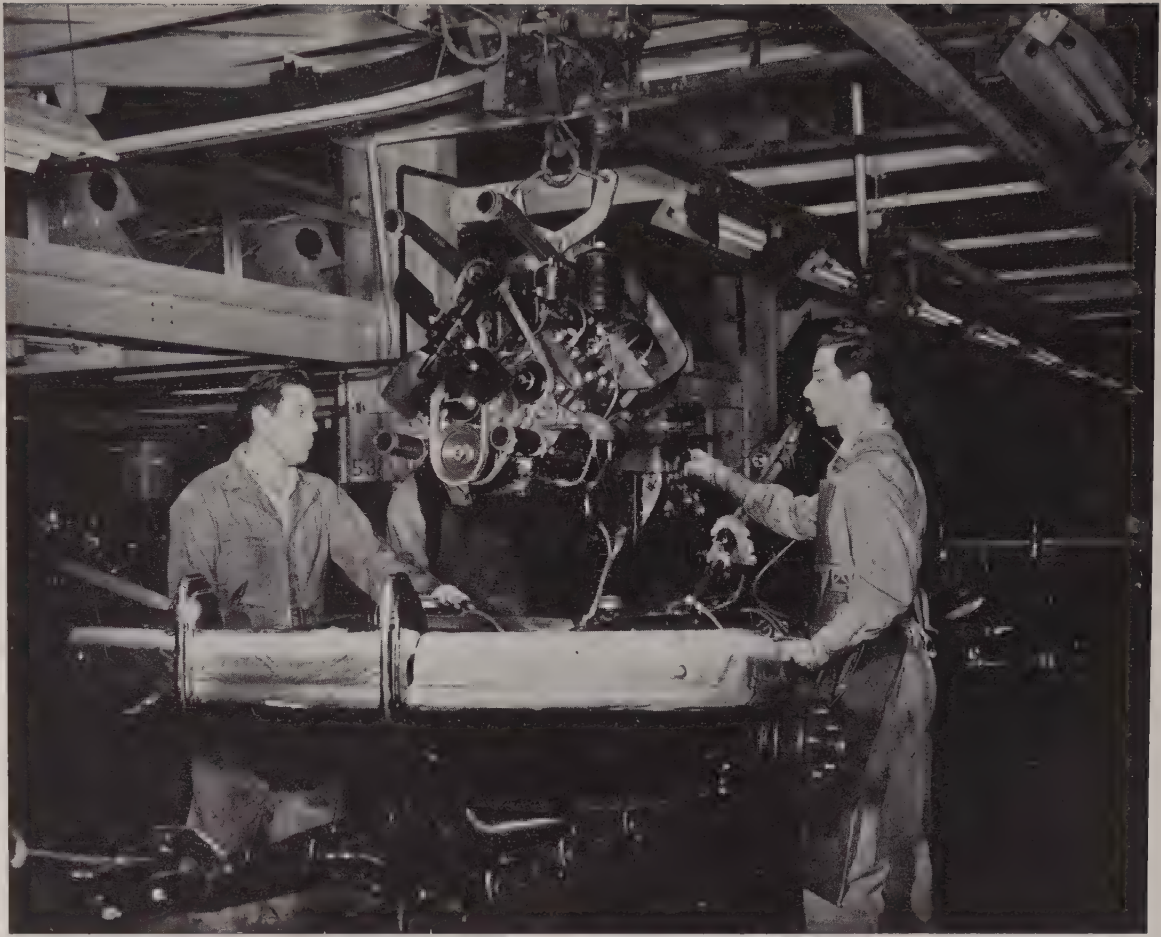


Fig. 68.—Showing the Final Angle obtained by using the Ring and Chain of the Lifting Bracket.



METHOD OF HOLDING AND LOWERING FORD ENGINE ON TO CHASSIS.

Disconnect the two change-speed operating shafts from their attachment to the selector levers by withdrawing the two bolts from each extremity of the T-shaped flanges, and then push these shafts outwards towards the chassis frame to provide clearance.

Disconnect clutch rods from their attachment to the levers on the clutch housing, and tie them together out of the way.

Remove front section of the exhaust down-pipe by detachment of four nuts on the flange joint and the pinchbolt gripping the rear end of the pipe.

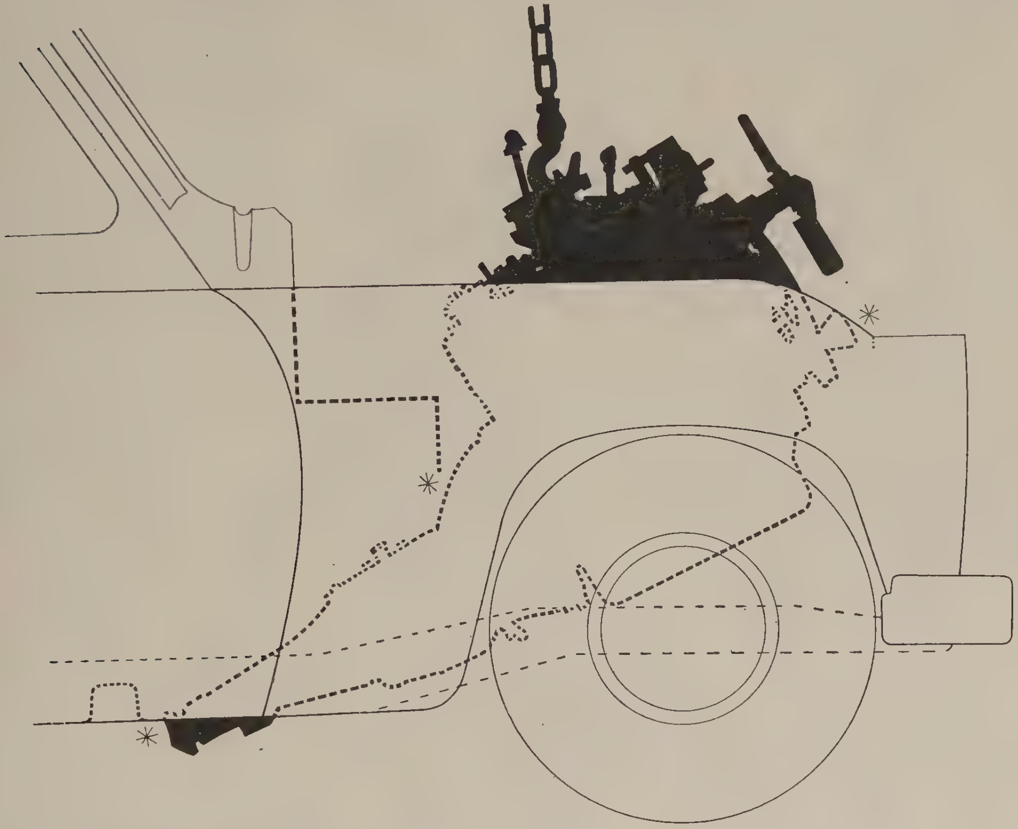


Fig. 69.—Removing Vanguard Engine Unit with Special Lifting Hook. The asterisks show the Points which necessitate the Angle of Tilt for withdrawal.

Withdraw the two bolts securing the extension flanged bracket to the rubber mounting on the chassis cross member.

Remove the two engine bearer bolts, one on each side-member bracket ($\frac{9}{16}$-in. A/F spanner). Remove starter motor.

Remove the engine by employment of a double sling, one round the fan pulley and the other round the back of the unit on the same principle as that illustrated in Fig. 72. Alternatively, employ a lifting bracket as illustrated by Fig. 69 after removal of rocker cover. The removal of the engine and gearbox will require a certain amount of manipulation if overloading of the gearbox extension by its pressure on the cross member is to be avoided when lifting, as it is necessary to clear body details. A suitable lifting bracket, as shown in Fig. 69, is made by Messrs. V. L. Churchill & Co., London.

Removal of Austin 2- and 3-ton Lorry Engine

The Austin six-cylinder commercial-vehicle engine, of 3·35 in. bore and 4 in. stroke, is removed from the chassis in the following manner:

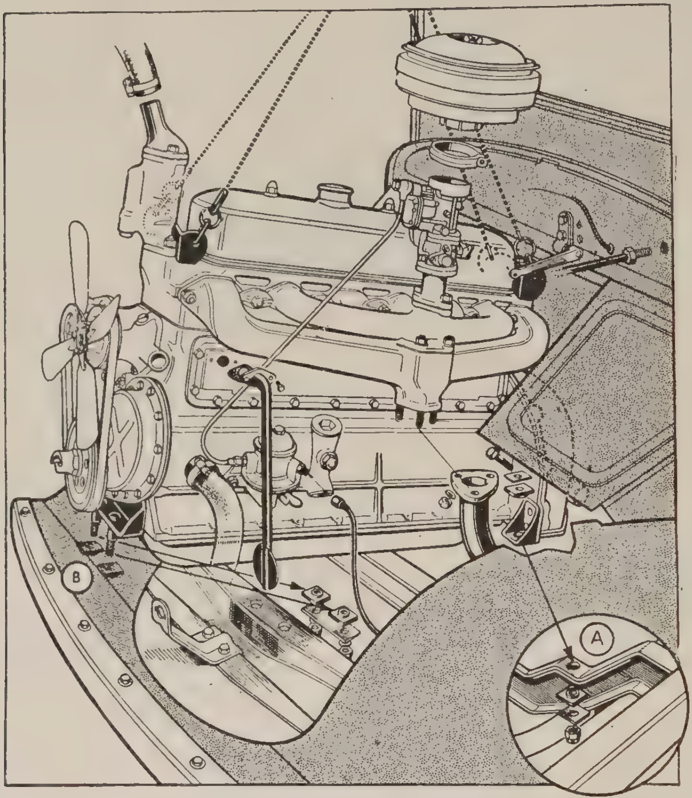


Fig. 70.—Method of Removing Austin Lorry Engine from Chassis.

Remove radiator. Disconnect propeller shaft and part gearbox from flywheel housing.

Disconnect battery (under front seat).

From underneath vehicle, remove the engine steady stay, held by stud on offside of crankcase near starter motor, and one bolt through offside chassis member. Also remove clutch pedal and bracket bolted to offside of crankcase. Remove starter motor lead and starter motor control wire and switch lever.

The two front holding-down bolts shown at B (Fig. 70) should next receive attention. Remove nuts, steel washers, and rubber packing washers. There are also rubber packing pieces between engine and chassis members, but these are only accessible when engine is raised and studs are clear of frame.

Disconnect oil pipe from offside of crankcase.

Disconnect fuel supply pipe, remove air filter and disconnect choke control wire. The carburettor need not be disconnected, but accelerator control must be detached.

Disconnect petrol pipe from pump on side of crankcase and also crankcase breather pipe, exhaust pipe, starter control cable, and H.T. cable from distributor. The dynamo leads should next be disconnected.

The engine is now ready for lifting out. The brackets under the front and rear pairs of cylinder-head studs should be used, the brackets being drilled to take the hooked ends of the lifting chains.

Alternatively, ropes slung under the engine at the front and rear sump extremities and tied under the overhead valve cover can be used. The engine whilst being lifted must be tilted upward, so that the front holding-down studs clear the chassis. Once they are clear, the engine unit can be drawn forward to clear the sump.

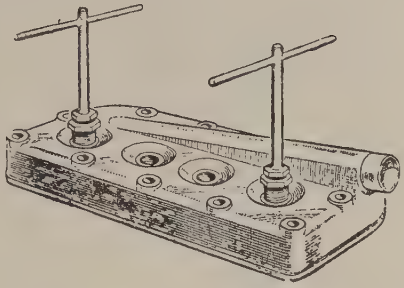


Fig. 71.—Cylinder-head Lifting Devices.

Miscellaneous Notes on Dismantling

It is much better to remove the radiator from the frame immediately the water has been emptied out, as this will not only simplify the subsequent dismantling operations, by enabling the worker to get all round the engine, as it were, but it will facilitate the removal of the complete unit. In the case of the combined engine and gearbox unit, it is generally impossible to get this out of the chassis without first removing the radiator.

The gear and brake levers must also be disconnected (or removed, as the case may be) when the gearbox is an integral unit with the engine.

The engine can be lifted out of the frame, either by employing the special eye-bolts or lifting plates, often supplied by the makers for screwing into the sparking-plug holes, or by placing a rope or chain sling around the complete unit (Fig. 72). A garage floor crane such as the "Jackrane" is best for the actual lifting operation.

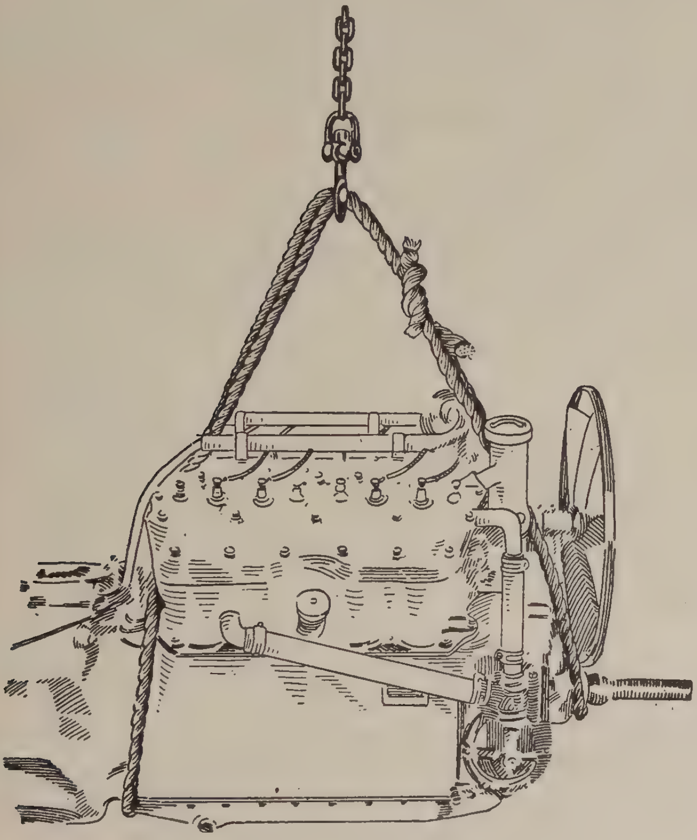


Fig. 72.—Method of Slinging an Engine.

On first lifting, it will sometimes be found necessary to shift one side or other of the sling so as to keep the engine trim.

When using a sling, do not let it put any stress on the inlet or exhaust manifold whilst lifting, to obviate risks of fracture.

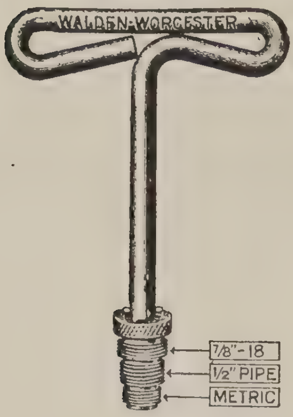


Fig. 73.—The Walden Cylinder-head Lifter.

The Walden cylinder-head tool, shown in Fig. 73, is of particular convenience in the above respect. It enables the cylinder or cylinder head to be lifted without damaging the gaskets or surrounding parts. The tool in question has three different sizes of screw adapter, viz. $\frac{7}{8}$ in. (18 threads), 14-mm. sparking-plug thread, $\frac{1}{2}$-in. pipe, and metric, so that any size of sparking-plug hole can be covered. There is a ratchet device between the T-handle and the screw adapter so that the tool can be used in confined spaces. These tools are supplied in pairs.

Another useful tool of a somewhat similar type is shown in Fig. 71. In this case the plugs and handles are fixed to each other.

The subject of vehicle-lifting appliances is dealt with in Volume II.

Breaking Cylinder-head Joint

In some designs of cylinder head, special projecting lugs (X, Fig. 74) are provided to facilitate the breaking of the joint and the lifting of same. With the aid of a piece of hard wood or soft metal, e.g. brass or copper rod, the head is tapped upwards on the faces at X. A copper or raw-hide hammer is also useful for this purpose.

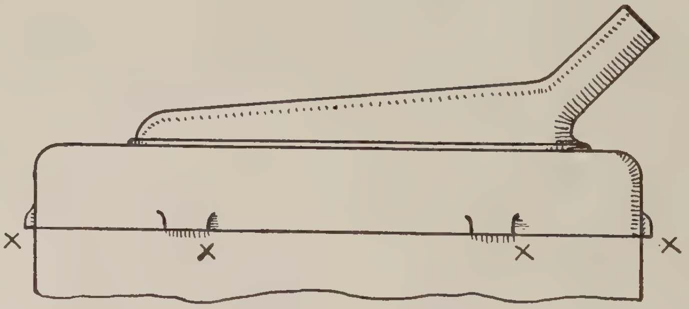


Fig. 74.—Lugs are provided at X on some Engines to facilitate the Cylinder-head Removal.

On no account should a steel wedge or screw-driver blade be used to break a cylinder-head joint as the machined faces would thereby be injured and, on replacing the head, a risk of water, gas, or compression leakage would occur.

A useful design of cylinder-head joint opening tool, known as the "Quickwork," illustrated in Fig. 75, consists of a strong U-bar having bosses A, which are bored at each end and the holes are exactly in line.

Into each hole, two shafts B, screw-threaded throughout their length, are provided with operating nuts C to move the hardened wedge-like ends of the shafts into the cylinder-head joint.

Depth-regulating sleeves D prevent the wedges from moving too far into the cylinder-head joint.

The shafts B are keyed in such a manner that they can be used, either with the wedge planes as shown in Fig. 75, or at right angles to this position. The same tool can also be used, with special fittings, for freeing heavy tyre covers which have become stuck in their rims.

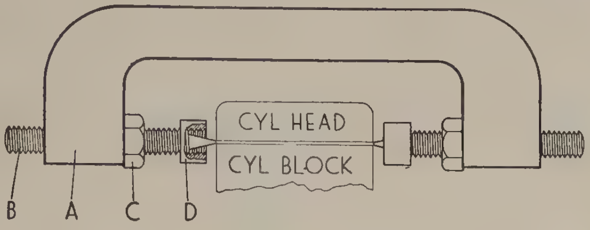


Fig. 75.—The "Quickwork" Cylinder-head Tool.

Dismantling Engine in Place

Hitherto we have been concerned with the removal, bodily, of the power unit; it is now proposed to describe the procedure for dismantling a car engine *in situ.* The difference between the two cases is that in that previously described it was necessary to disconnect all external attachments, whereas in the present case only those which get in the way of dismantling the engine need be disturbed. For example, it is unnecessary to detach electric cables to the switch or battery, to disconnect the flywheel clutch or intermediate shaft (unless the crankshaft is to be removed); or to disturb the engine mounting bolts on the chassis frame.

The following is a brief outline of the usual dismantling procedure in its order of occurrence:

Drain the radiator and remove the bonnet.

Disconnect and remove radiator from frame.

Detach exhaust manifold.

Disconnect engine controls, i.e. carburettor and ignition ones.

Remove carburettor bodily and, if convenient, inlet manifold.

Mark the sparking-plug leads, 1, 2, 3, 4, etc., and remove from plugs.

Remove detachable cylinder-head unit (see Figs. 127 and 128 for orders of unscrewing nuts).

Remove valve-operating push rods, if overhead-valve engine.

Remove valve cotters, collars, springs and, finally, the valves themselves.

Here it may be mentioned that it is possible to undertake the following operations upon the engine when in place on its chassis:

(1) Decarbonising the combustion chambers and valve ports, pistons, etc.
(2) Regrinding the valves on their seatings.
(3) Removal of pistons and connecting rods.
(4) Removal of main-bearing caps and crankshaft.
(5) Reboring of cylinder barrels with portable boring bar machine.

If, however, the engine has been in service for a considerable period and is due for a major overhaul, it is always advisable to remove it bodily from its chassis and take it to the bench, or engine stand, where every component can be removed more conveniently and expeditiously.

It is possible, however, to carry out overhauls or replacements to the timing gears or chains, oil and water pumps, and the small- and big-end connecting-rod bearings; also to remove and replace piston rings when a rebore is not yet necessary. New piston assemblies can be fitted to rebored engines when the latter are in their chassis.

Typical Engine Assemblies

In order to afford a general idea of the various components that are necessary in the modern high-speed petrol engine, the example of the Austin A70 engine has been selected as typical of high-grade design and construction. This engine is shown in external views in Figs. 76 and 77, the various external components being numbered and described alongside each illustration. Having thus become familiar with the external features of the engine so that their arrangement will serve as a guide when dismantling similar car engines, the reader should refer next to the "exploded" view of the same engine shown in Fig. 78. The design and relative dispositions of the internal components of this engine are clearly shown, so that the procedure for the more detailed stripping down of such engines will be rendered more easy than when verbal instructions only are given.

The engine illustrated in Figs. 76, 77, and 78 is a four-cylinder one having push-rod and rocker-arm overhead valves. The bore and stroke are 79·3 mm. and 111 mm. respectively, giving a cubic capacity of 2,199 c.c. The engine develops a maximum output of 64 b.h.p. at 3,800 r.p.m., and torque of 108 lb./ft. at 2,200 r.p.m. It has a compression ratio of 6·8 : 1.

Special constructional features include oil-cushioned rocker-arm valve-stem clearances, anodised aluminium-alloy pistons, duplex timing chain with synthetic rubber tensioner, flexible rubber mountings, and a novel improved method of lubricating the main and big-end bearings. The main and big-end bearings are of the whitemetal-lined steel semi-shell type.

Another example of a modern commercial vehicle petrol engine is that of the Morris CV unit, shown sectionally in Fig. 79, and in detailed and numbered "exploded" view in Fig. 80.

The engine is a four-cylinder one, of bore and stroke 100 mm. and 112 mm. respectively, giving a cubic capacity of 3,519 c.c. The compression ratio is 5·7 : 1, and the R.A.C. rating 24·8 h.p.

The CV10/5 engine develops 70 b.h.p. at 2,850 r.p.m.

The various design and constructional features and the number and dispositions of the various components will be apparent after a close study of Fig. 80 and the explanatory key to the numbers, so that the service

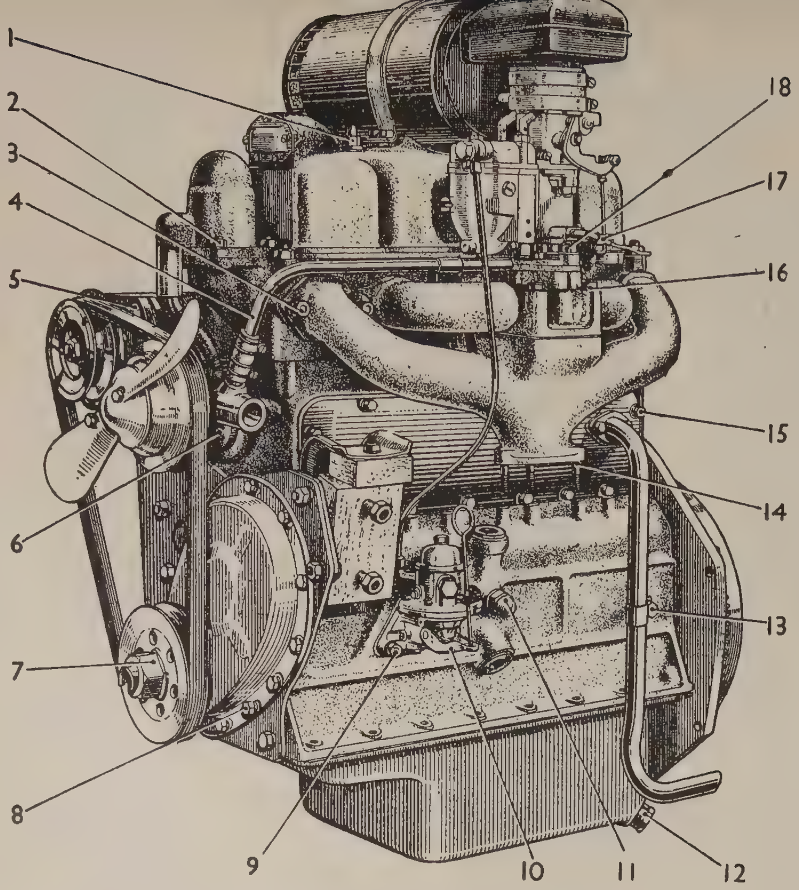


Fig. 76.—The Austin A70 Power Unit. (Near-side View).

The left-hand side of the power unit showing: 1, Valve Rocker Cover Cap Nut. 2, Water-outlet Pipe Nuts. 3, Exhaust-manifold Nuts. 4, Heater Water-outlet Pipe. 5, Dynamo-bracket Locking Nut. 6, Water Pump. 7, Starting Nut. 8, Timing cover Screw. 9, Petrol-pump Flange Nut. 10, Petrol-pump Priming Lever. 11, Cap Nut for Oil-pump Locating Screw. 12, Drain Plug for Sump. 13, Breather Pipe. 14, Exhaust-pipe Flange Studs. 15, Nuts for Cylinder Side Cover. 16, Set-screws. 17, Elbow and Union for Vacuum Pipe. 18. Carburettor Flange Nuts.

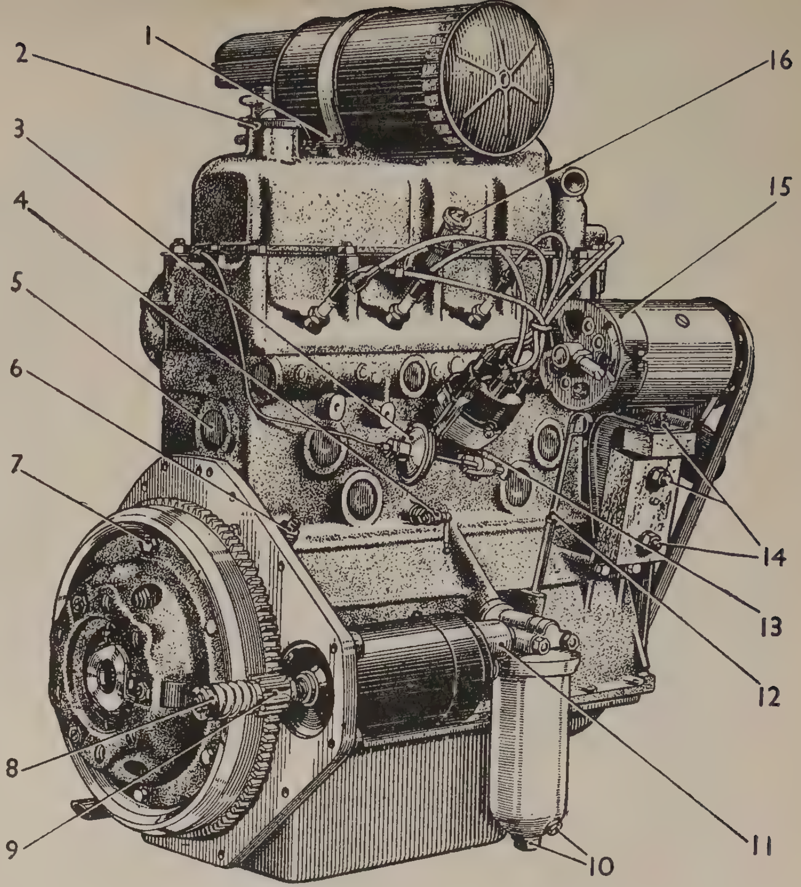


Fig. 77.—The Austin A70 Power Unit. (Off-side View).

The right-hand side of the power unit showing: 1, Air Cleaner Strap Bolt. 2, Oil-filler Cap. 3, Vacuum-timing Control. 4, Water-drain Tap. 5, Welch Plug. 6, Oil-gauge Union. 7, Clutch-cover Screws. 8, Starter-motor Shaft Nut. 9, Starter Pinion and Sleeve. 10, Full Flow Filter Retaining Screw and Drain Plug. 11, Starter-motor Switch. 12, Dipstick. 13, Distributor Clamp Bolt. 14, Engine-mounting Bolts. 15, Dynamo Commutator Cover. 16, Interior Heater-control Valve.

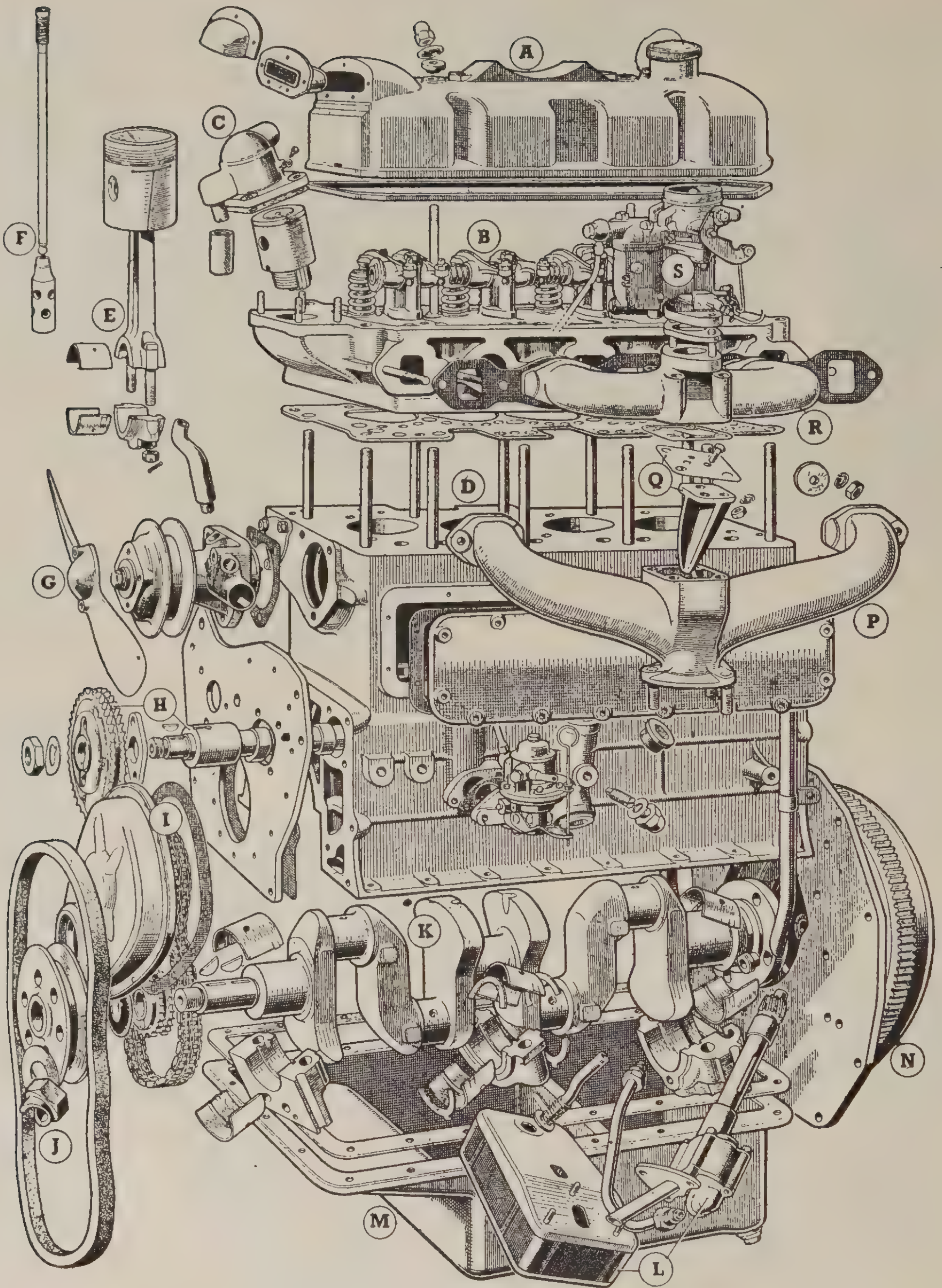


Fig. 78.—The Components of the Austin A70 Power Unit.

A, Valve Cover, Breather and Oil-filler Cap. B, Cylinder-head Assembly. C, Thermostat. D, Crankcase. E, Connecting Rod, Piston, Bearing Cap and Bearings. F, Push Rod and Tappet. G, Fan and Water-pump Assembly. H, Camshaft and Cam Gear. I, Timing-gear Cover and Timing Chain. J, Starting Nut, Pulley, Fan and Dynamo Belt. K, Crankshaft, Bearings, Bearing Caps and Sprocket. L, Oil Pump and Strainer Assembly. M, Oil Sump. N, Flywheel. P, Exhaust Manifold. Q, Hot Spot. R, Induction Manifold. S, Carburettor.

engineer should be able to tackle the dismantling and also reassembly of similar engines.

In many commercial-engine designs there are large inspection doors on the sides of the crankcase, to enable the big-end-bearing cap bolts to be removed, so as to permit of the withdrawal of the connecting rods and pistons without removing the cylinders. The usual procedure in such cases is first to remove the detachable cylinder head, then take out the split pins of the big-end cap bolts, remove the castle nuts and take the caps off. The connecting rod (with piston attached) can usually be pushed upwards in the cylinder until the piston is quite clear of the top of the cylinder, when it can be removed.

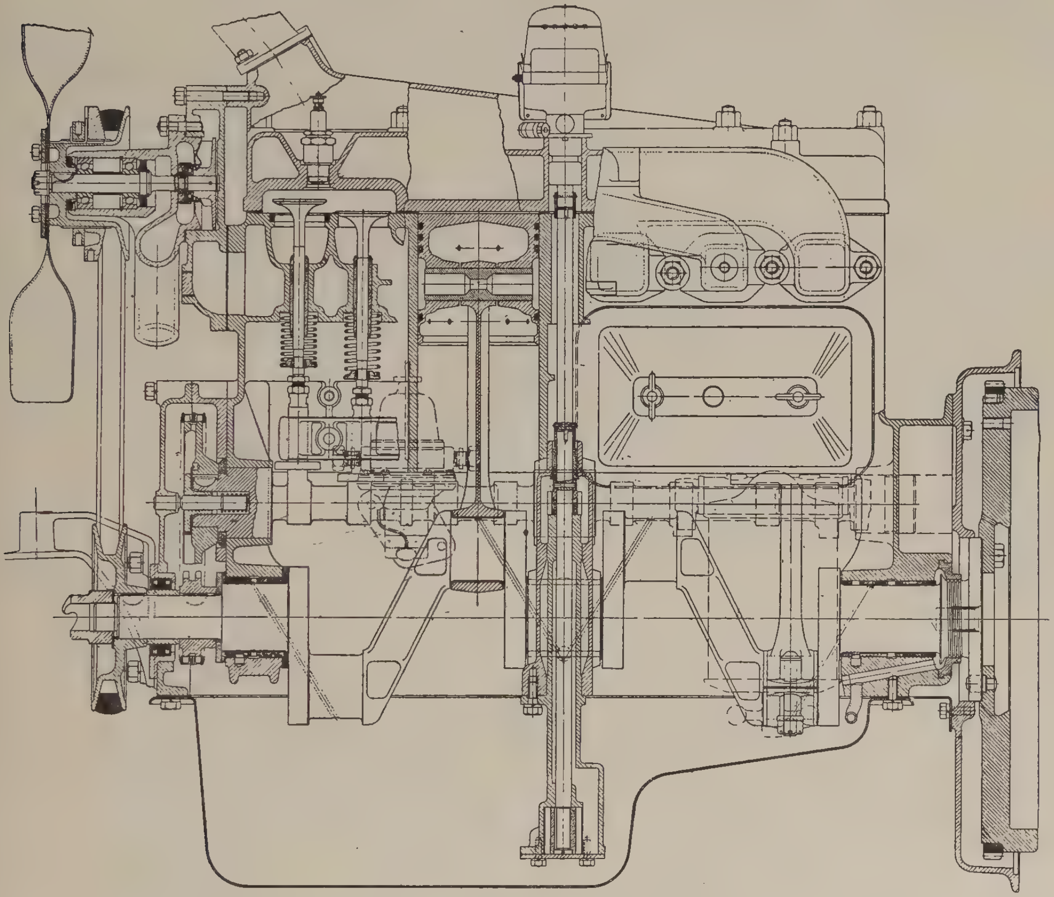


Fig. 79.—The Morris CV Commercial-type Engine in Part Sectional View.

Each connecting rod and piston can be removed in this way, and the big-end bearings can then be refitted in turn, without disturbing the cylinder block.

The same remarks apply more or less generally to most modern engine-

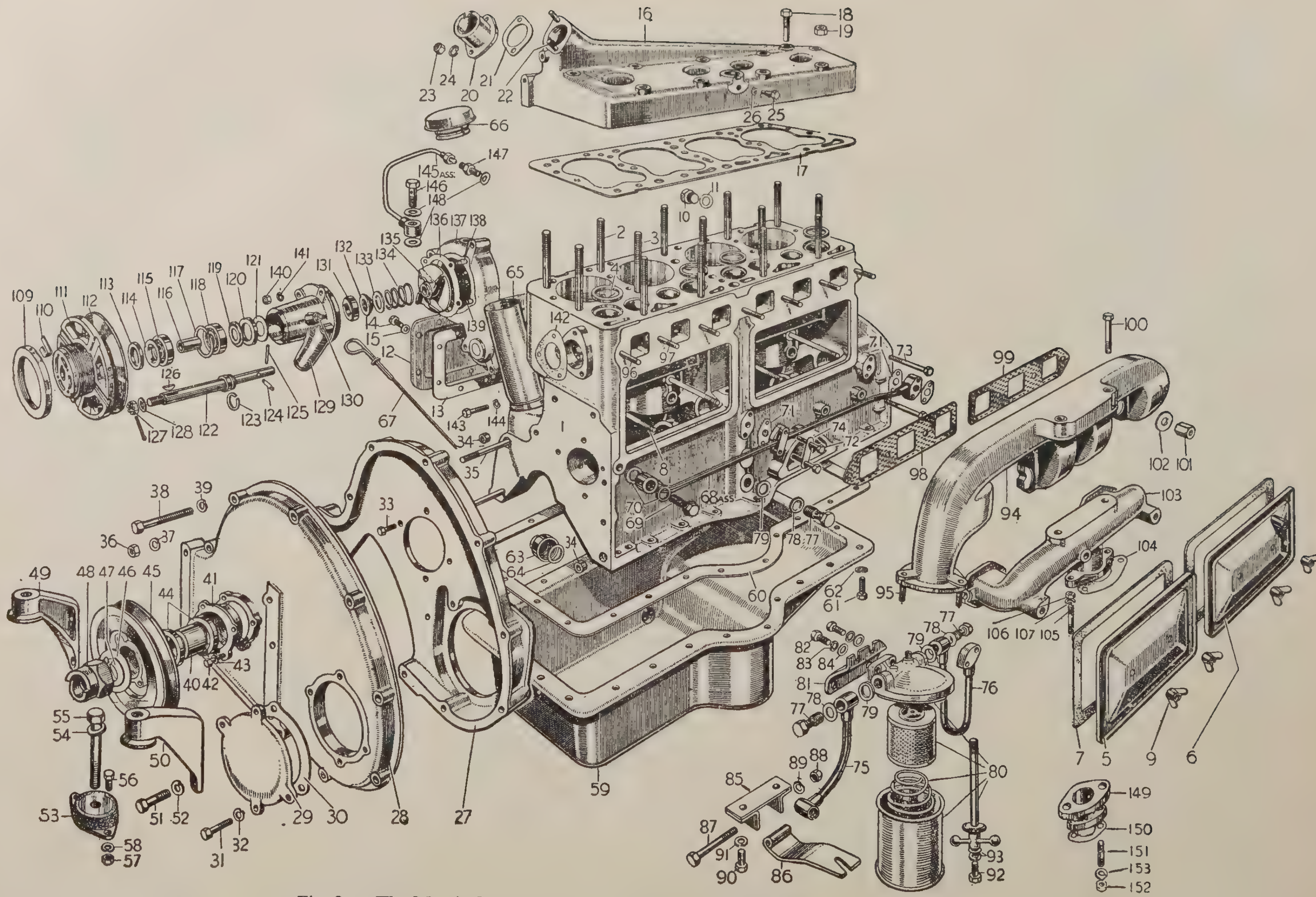


Fig. 80.—The Morris CV Commercial-type Side-valve Engine, shown in Exploded View.

The Morris CV Commercial-type Side-valve Engine Components

Key to Numbers in Fig 80

1. Cylinder block assembly (Austenitic liners are fitted for models CV10/5 and CVF13/5 only).
2. Stud for cylinder head (short).
3. Stud for cylinder head (long).
4. Exhaust valve seat inserts (Models CV11/30 — 9/40T — CV11/40). Exhaust valve seat insert with locking-spring ring (Models CV10/5 and CVF13/5 only).
5. Cover for tappet chamber (front).
6. Cover for tappet chamber (rear) with fume extractor tube.
7. Joint for tappet-chamber cover.
8. Stud for tappet-chamber cover.
9. Wing nut for tappet-chamber cover.
10. Water drain plug for cylinder block.
11. Fibre washer for drain plug.
12. Water-jacket cover.
13. Joint for water-jacket cover.
14. Set bolts for water-jacket cover.
15. C. & A. washers and plain washers for ditto.
16. Cylinder head.
17. Gasket for cylinder head.
18. Timing plug.
19. Nut for cylinder-head studs (in cylinder block).
20. Water outlet pipe.
21. Joint (water outlet pipe to cylinder head).
22. Stud for water outlet pipe.
23. Nut for ditto.
24. Spring washer for ditto.
25. Set bolt locating distributor.
26. Spring washer for ditto.
27. Timing chain case.
28. Cover for timing chain case.
29. Cover for dynamo chain wheel.
30. Joint for ditto.
31. Set bolt for ditto.
32. Spring washer for ditto.
33. Set bolt, timing chain case to cylinder block.
34. Dowel for timing chain case.
35. Set bolt, timing chain case and cover to cylinder block.
36. Nut for set bolt.
37. Spring washer for ditto.
38. Set bolt, timing chain case cover.
39. Spring washer for ditto.
40. Distance collar for crankshaft oil seals.
41. Housing for oil seals.
42. Set bolt for housing.
43. Spring washer for set bolt.
44. Oil seals.
45. Fan pulley for crankshaft.
46. Spring washer for starting-handle jaw.
47. Spring for starting-handle jaw.
48. Jaw for starting handle.
49. Front support bracket for engine (off side).
50. Front support bracket for engine (near side).
51. Bolt for bracket.
52. Spring washer for ditto.
53. Flexible mounting.
54. Plain washer for bolt.
55. Set bolt for flexible mounting.
56. Bolt, flexible mounting to frame bracket.
57. Nut for bolt.
58. Spring washer for bolt.
59. Oil sump.
60. Gasket for oil sump.
61. Set bolt, sump to cylinder block.
62. Spring washer for ditto.
63. Drain plug for sump.
64. C. & A. washer for drain plug.
65. Oil-filler tube.
66. Oil-filler cap.
67. Dip rod for oil level.
68. Main oil-pipe assembly.
69. Pin for banjo connection.
70. Fibre washer for pin.
71. Joint for main oil-pipe connections.
72. Set bolt for centre connections.
73. Set bolt for rear connections, joint, and locking plate.
74. Locking plate for set bolts.
75. Oil-pipe assembly, cylinder block to filter.
76. Oil-pipe assembly, filter to rear of main oil-pipe.
77. Pin for oil-pipe connections.
78. Fibre washer for pin.
79. C. & A. washer for pin.
80. Oil-filter assembly.
81. Support bracket for oil filter.
82. Set bolt, bracket to filter.
83. Spring washer for ditto.
84. Plain washer for ditto.
85. Steady bracket to sump.
86. Steady bracket to filter.
87. Bolt, steady bracket.
88. Nut for bolt.
89. Spring washer.
90. Set bolt, steady bracket to sump.
91. Spring washer for bolt.
92. Set bolt, steady bracket to filter.
93. Spring and plain washer to ditto.
94. Exhaust manifold.
95. Stud for exhaust manifold flange.
96. Stud (short) manifold to cylinder block.
97. Stud (long) manifold to cylinder block.
98. Gasket (front), for manifolds.
99. Gasket (rear), for manifolds.
100. Set bolt (induction manifold to exhaust manifold.
101. Nut for manifold studs (in cylinder block).
102. Plain washer for ditto.
103. Inlet manifold.
104. Joint, carburetter to inlet manifold.
105. Stud, inlet manifold to adapter.
106. Nut for stud.
107. Spring washer for stud.
109. Locking ring for fan pulley flange.
110. Locking piece for lock ring.
111. Flange for pulley.
112. Pulley.
113. Dust excluder (felt) for ball bearing (front).
114. Cover for front dust excluder.
115. Ball bearing (front).
116. Distance piece between bearings.
117. Circlip for ball bearing (rear).
118. Ball bearing (rear).
119. Cover for rear dust excluder.
120. Dust excluder (felt) for ball bearing (rear).
121. Plate for rear dust excluder.
122. Fan spindle.
123. Circlip for spindle.
124. Peg for carbon seal.
125. Taper pin, impeller to spindle.
126. Key for fan spindle.
127. Castle nut for front of spindle.
128. Plain washer for ditto.
129. Water pump body (front half).
130. Oil-gun nipple for ditto.
131. Carbon seal and ring assembly.
132. G.A.C.O. seal.
133. Washer for G.A.C.O. seal.
134. Spring for ditto.
135. Pump impeller.
136. Joint, water-pump body, front half to rear half.
137. Water-pump body, rear half.
138. Stud (short), front half to rear half.
139. Stud (long), ditto.
140. Nut for studs.
141. Spring washer for ditto.
142. Joint, water pump to cylinder block.
143. Set bolt, water pump to cylinder block.
144. Spring washer for set bolt.
145. Air-release pipe assembly.
146. Banjo pin.
147. Union, pipe to cylinder head.
148. Fibre washer for banjo pin and union.
149. Flange adapter for carburettor.
150. Joint for adapter.
151. Stud, carburettor.
152. Nut for stud.
153. Spring washer.

cylinder designs, in which the cylinder barrels are cast integral with the top half of the crankcase.

In some designs of petrol and Diesel engines, notably the larger ones used in commercial vehicles, *the big-end portion of the connecting rod is too large to pass through the cylinder barrel*, so that the procedure for dismantling the piston and connecting rod is different from that described previously.

In this case the connecting-rod cap should first be taken off, and if shell-type bearings are fitted these must be removed also, taking care first to mark them so as to ensure that they are replaced in the correct positions. Having removed the cap, the connecting rod is then pushed up as far as it will go. It will then be found that the piston will rise sufficiently far above the machined face of the cylinder block to expose the ends of the gudgeon pin. The latter should then be removed from the piston by whatever method is dictated by the pin fixing. The piston can then be pulled out of its barrel whilst taking the weight of the connecting rod. Finally, the latter is lowered and can be removed from below. This procedure is repeated for each piston in turn, until all have been removed.

Dismantling Typical Oil Engine

The method of dismantling a typical commercial-vehicle high-speed oil engine is well illustrated by the example of the six-cylinder A.E.C. engine, as used by the London Transport Board. The engine in question is shown in Fig. 81. It has a bore of 115 mm. and a stroke of 142 mm., developing 130 b.h.p. at 1,700 r.p.m.

The engine, in common with most other British oil engines in use for commercial motors, has overhead air and exhaust valves which are operated by means of push rods and rocker arms from a camshaft carried in the cylinder block. The *camshaft* is driven from the crankshaft by means of a triple roller chain, which also drives the radiator cooling fan, the water pump, dynamo, vacuum exhauster for operating the Servo vacuum brake, and the fuel-injection pump. The two latter components are mounted in tandem on the near-side of the engine, whilst the water pump, which is mounted on the forward side of the crankcase, is driven by an extension of the dynamo shaft. The *water pump* is fitted with a special carbon packing (Fig. 82) which requires no attention; this does away with the constant nuisance of re-packing the spindle.

Full-pressure lubrication is provided for the main and big-end bearings, and a special metering device feeds a small quantity of oil to the overhead valve gear from the main oil pump.

Three-point suspension is provided for the engine unit, the front of the engine being carried by a removable cross-member bolted on to the dumb irons and fixing to a bracket on the front of the crankcase, which carries the starting handle.

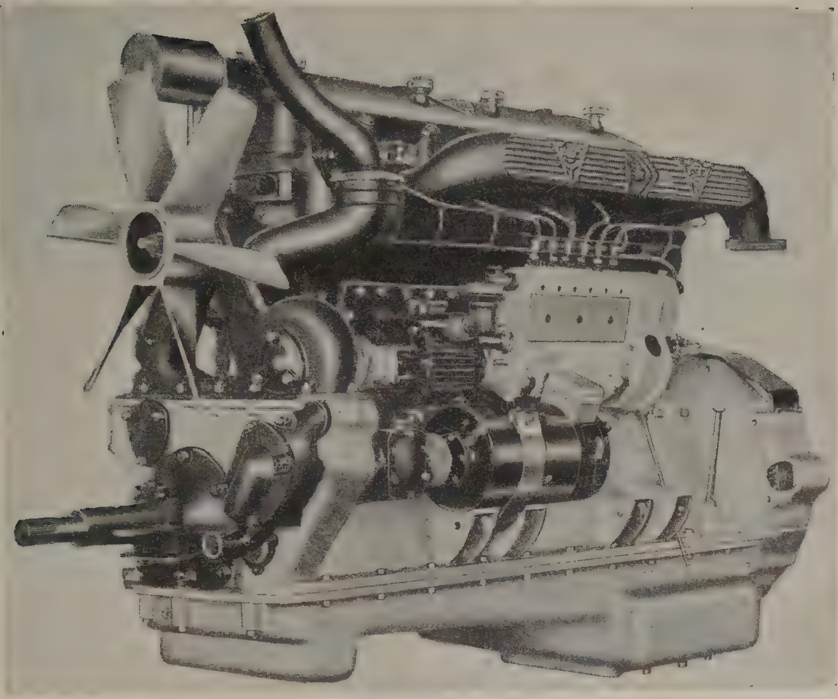


Fig. 81.—The A.E.C. Six-cylinder Oil Engine.

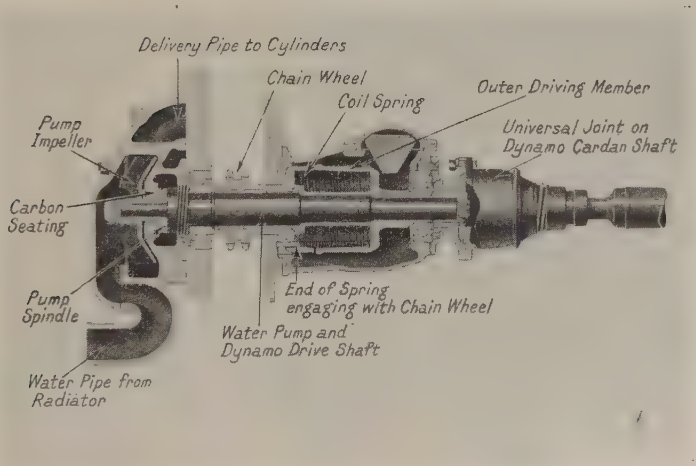

Delivery Pipe to Cylinders
Chain Wheel
Coil Spring
Outer Driving Member
Universal Joint on Dynamo Cardan Shaft
Pump Impeller
Carbon Seating
Pump Spindle
End of Spring engaging with Chain Wheel
Water Pump and Dynamo Drive Shaft
Water Pipe from Radiator

Fig. 82.—The A.E.C. Water-circulation Cooling Pump, having Carbon Packing for the Drive Shaft.

Removal of Cylinder Heads

The cylinder heads are formed in two units, each covering three cylinders; they are interchangeable. The valve mechanism is carried in the head and is totally enclosed by a cover, which also forms the air-intake pipe (Fig. 83).

The *valve springs are replaceable* without removing the valves. To do this, the rocker shaft, complete with its brackets and rockers, must first be removed, after disconnecting the oil pipes feeding the rocker bearings. The piston is then brought to its top dead centre when, owing to the very small clearance between the piston and cylinder head, the valve springs can be removed without displacing the valves.

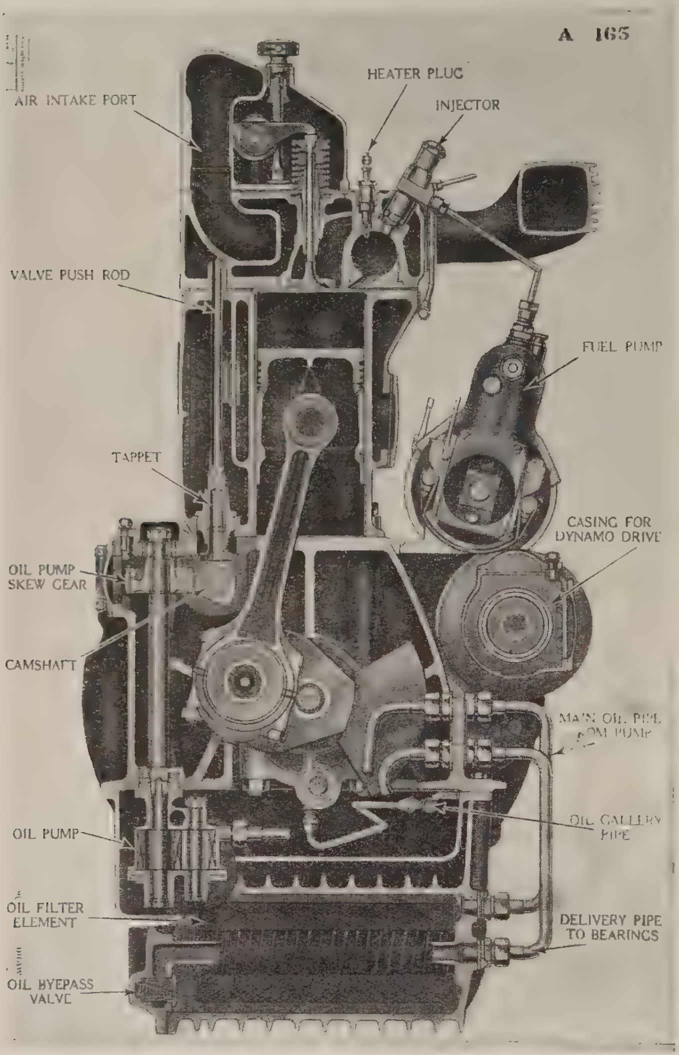


Fig. 83.—Sectional View of A.E.C. Oil Engine.

The *cylinder heads* are removed separately, the method being practically identical for each head; it is as follows:

Remove the cylinder-head cover. Disconnect the top water pipe; it is generally easier to break the flanged joint on the cylinder head rather than disturb the rubber connection. Next, remove the bus-bar from the electric heater plugs and disconnect the injector pipes.

Disconnect the exhaust-pipe flange and uncouple the two halves of the exhaust manifold where it is joined in the centre. Remove the water pipe, coupling the two heads together at the near-side of the engine, and disconnect the water-feed pipe from the back head. Remove the rockers and brackets, and, for convenience, lift out the push rods operating the valves.

Two special jack nuts (Fig. 85) are fitted to each head to facilitate removal, and are so arranged that as they are unscrewed they will lift the head clear of the cylinder. *These two nuts must, therefore, not be unscrewed*

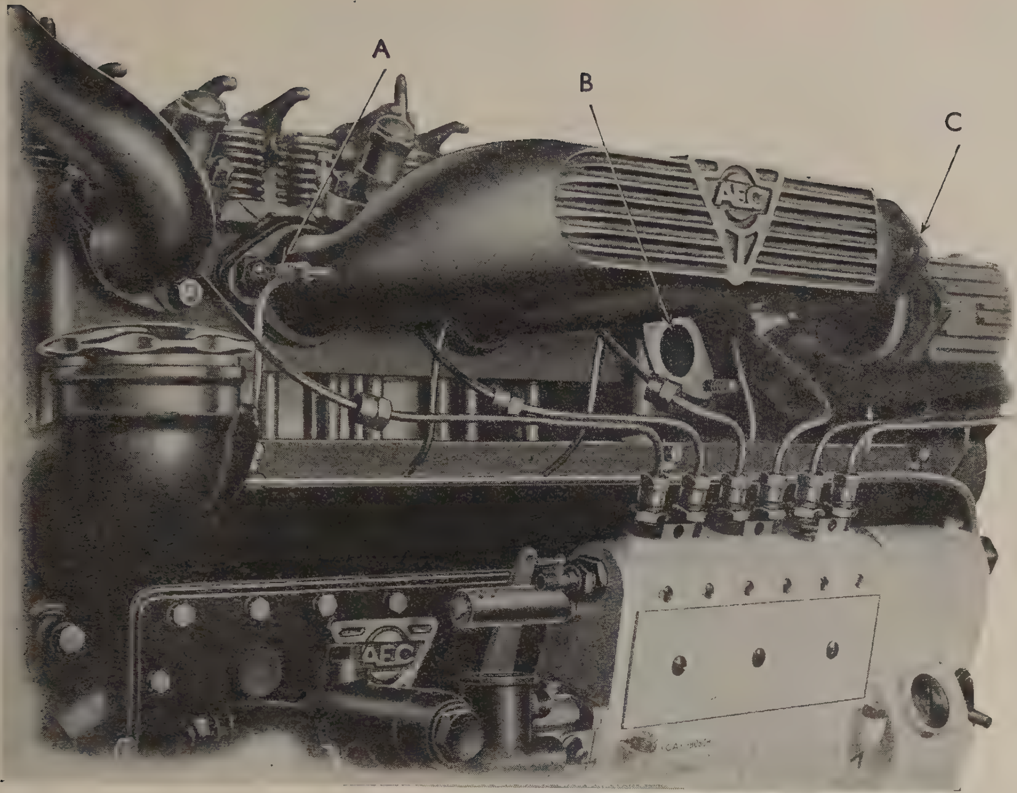


Fig. 84.—The Cylinder-head Removal.

A—Fuel Pipes Uncoupled. B—Water-pipe Removed. C—Exhaust Pipe Uncoupled.

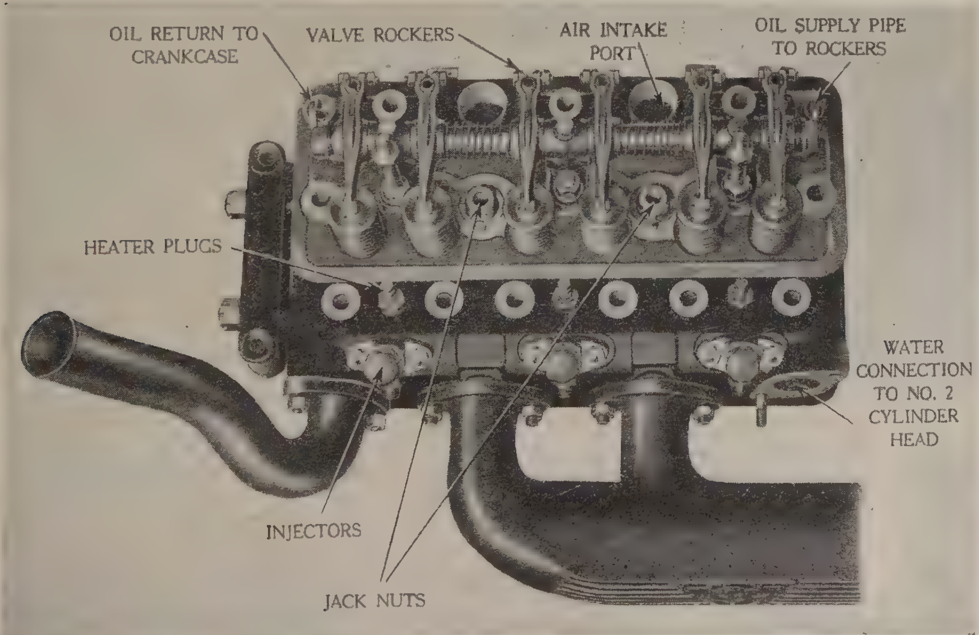


Fig. 85.—The Cylinder Head of A.E.C. Engine, showing Jack Nuts for Facilitating Removal.

until all the other nuts have been removed. When this has been done unscrew the two jack nuts evenly until the nuts are disengaged from their studs.

Removing the Pistons

The pistons must be removed by passing the connecting rod up the cylinders (Fig. 86), since they cannot be removed through the crankcase. Remove the cylinder-head and also the sump. Next, remove the connecting-rod caps. Push the piston up the cylinder until it can be grasped from above and the piston with its connecting rod lifted clear of the cylinder. Take care that the rod does not score the cylinder barrel when passing through it.

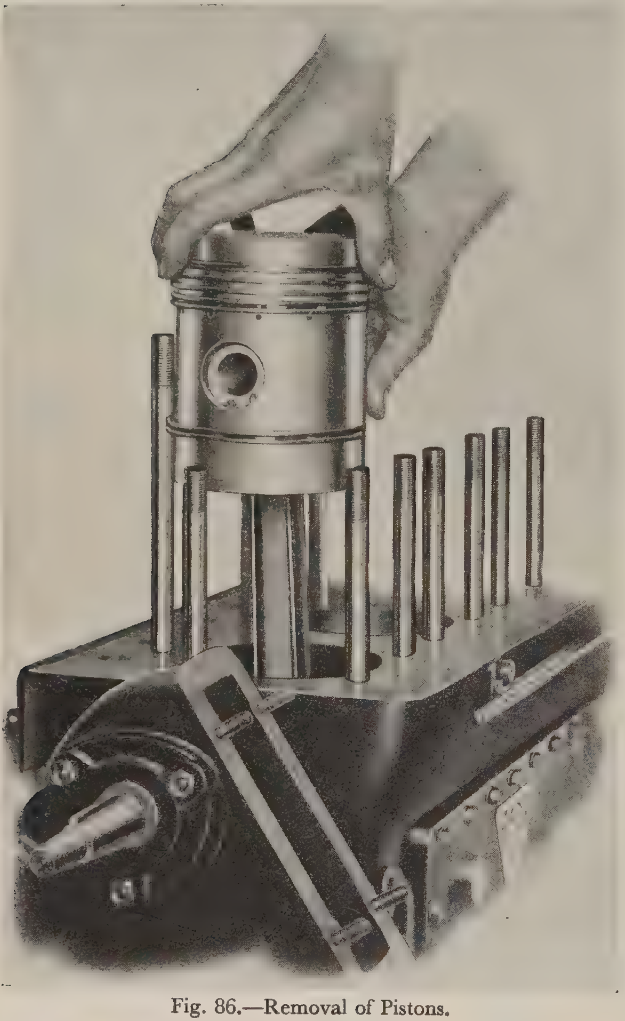


Fig. 86.—Removal of Pistons.

The gudgeon pin floats in both the piston and the connecting rod, and is secured endwise by a circlip spring ring, which opens out into a groove in the gudgeon-pin hole of the piston.

To remove a circlip ring, a special pair of pliers with circular jaws is required.

The *fit of the gudgeon pin* in the piston should be such that when the piston is at ordinary room temperature the pin can be forced in by the pressure of the two thumbs. On no account should the piston bosses be reamered out. When fitting new gudgeon pins, they should be selected to give the correct fit.

Removing the Cylinder Block

After removing the cylinder head and push rods, remove the fuel pump and the exhauster, previously mentioned. There are packing shims under the exhauster which should be replaced when reassembling. Remove the cover over the top of the timing case so that when the block is lifted the camshaft gear and the front camshaft bearing will be removed complete with the block. On removing the nuts which hold the block to the crankcase, the block can be lifted off. It is highly desirable that the pistons be drawn before the block is lifted, as the replacement of the block over the six pistons is a rather difficult operation, particularly if working in the restricted space of the cab.

The Timing Case

To remove the timing case, the radiator and the cylinder block must first be removed, as previously described. Then break the chain (Figs. 87 and 88), remove the nuts securing the timing case to the engine, and lift up the timing case, allowing each end of the chain to unwrap. For breaking the chain, a rivet extractor is provided in the tool kit.

Removing the Fan Spindle

Remove the fan, using the draw dog supplied in the tool kit, and remove the top cover from the timing case. This will expose the fan spindle, on which the chain sprocket and the camshaft driving gear are mounted on a long taper. After breaking the chain, the complete fan spindle can be lifted bodily out of the timing case.

Remove Exhauster and Fuel-pump Drive Spindle

The construction of this spindle is similar to the fan spindle, the removal method being the same, except that in this case the spindle is knocked out from the front instead of from the back. The front ball race is left in the timing case and the rear one comes away with the cover and spindle.

To Remove Water Pump and Dynamo Drive Spindle

Remove the water pump by unscrewing the two lower nuts on the cover for the pump casing, and also by removing the long bolt going through the water pump, crankcase, and water pipe. By pulling the pump straight forward off its studs, it can be removed. Remove the dynamo and coupling flange on the end of the drive spindle. Remove the casing containing the free-wheel drive for the dynamo and drive out the spindle towards the front of the engine. The sprocket wheel, the ball bearing at the dynamo end, and the oil-thrower disc will be stripped off, while the bearing at the water-pump end, together with its thrower, will remain on the shaft.

It should be noted that it is unnecessary to remove either of the auxiliary

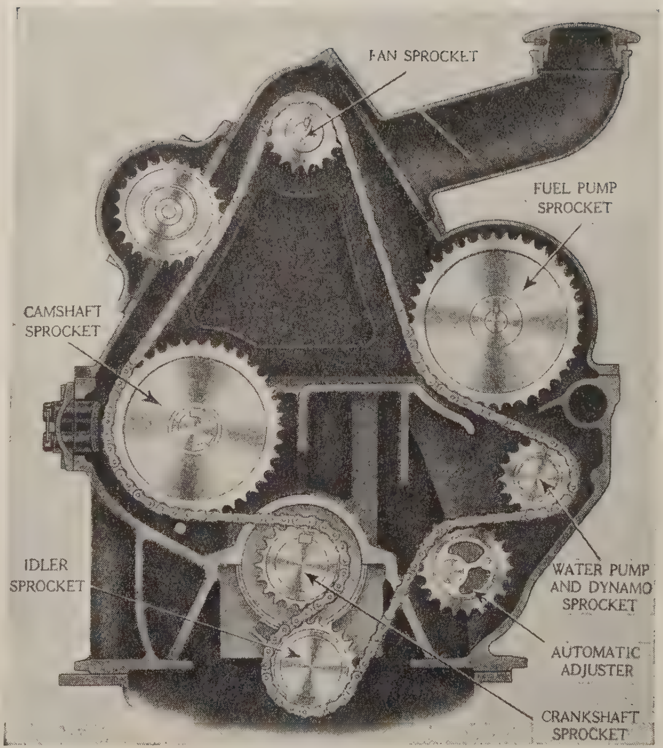


Fig. 87.—The Timing Gears and Roller-chain Drive.

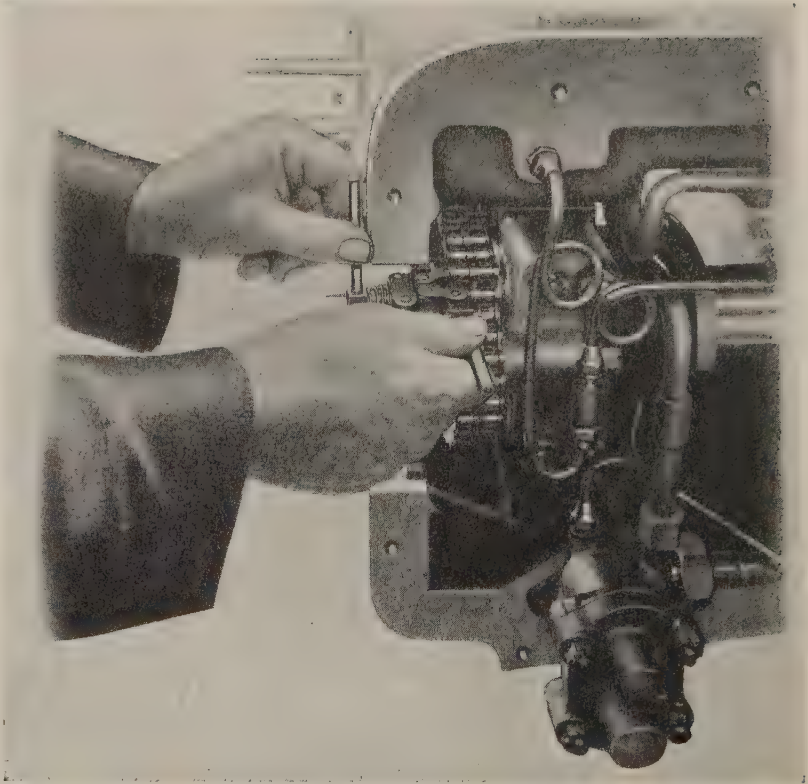
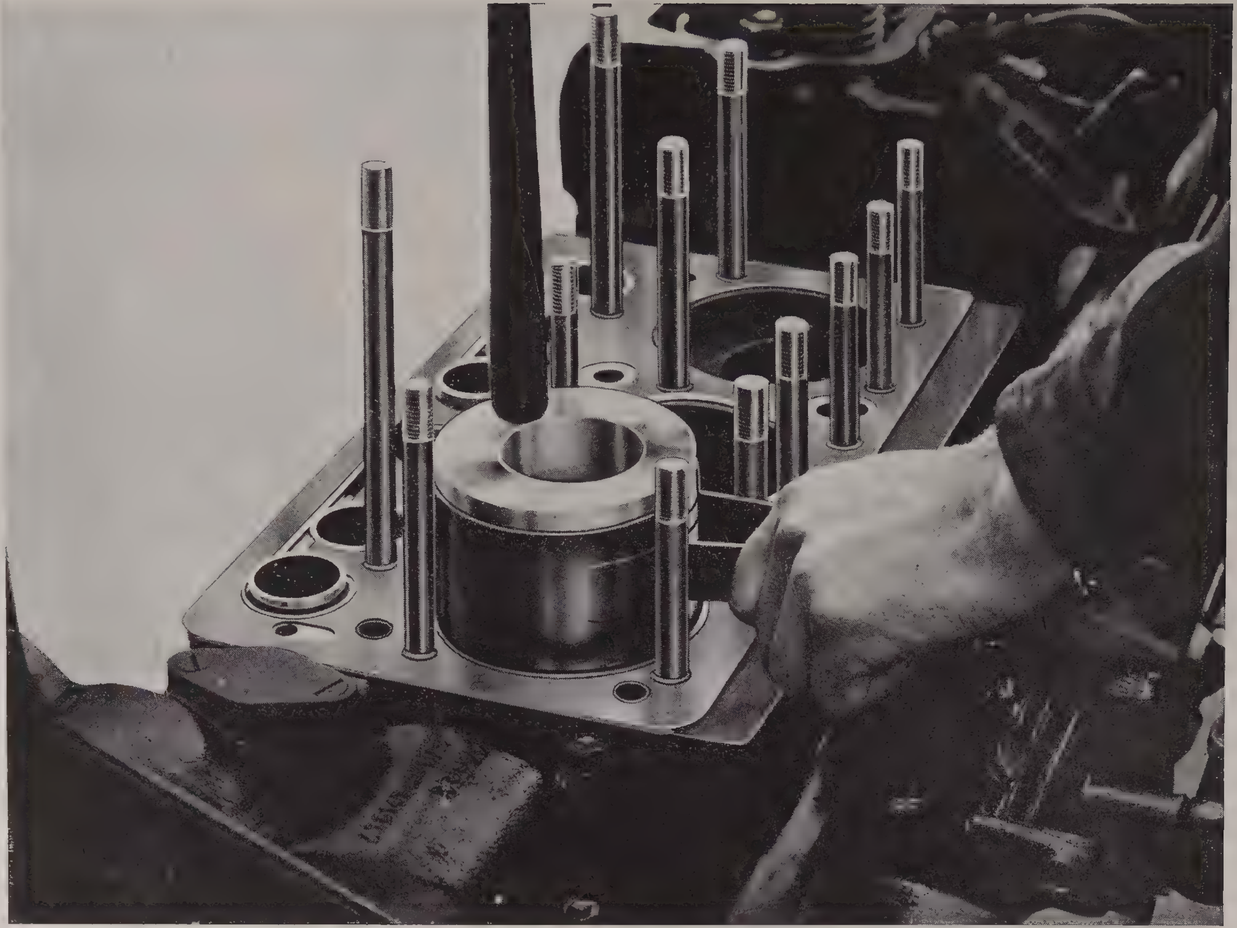


Fig. 88.—Using the Rivet Extractor to Break Timing Chain.



ILLUSTRATING METHOD OF REPLACING A.E.C. DIRECT-INJECTION ENGINE PISTON IN CYLINDER BARREL.

shafts unless the sprockets or one of the bearings become worn and require renewal.

To Remove Timing-chain Tensioner

The chain tensioner is situated in the crankcase, and it is necessary for the water pump to be removed before access can be made to this unit. Next, release the spring by freeing the outer end from the slot in which it is located. The eccentric, complete, can then be pulled out. When removing the tensioner while the timing case and the chain are in position, the sprocket will be stripped off the eccentric as the latter is removed.

To Remove the Camshaft

It is advisable, for the sake of expediency, to remove the engine from its chassis before attempting to remove the camshaft. It is possible, too, to remove the camshaft without removing the pistons, connecting rods, and crankshaft, but the makers suggest that these should be removed beforehand. If these items are still in place, the procedure is as follows:

The sump must be removed; also the tappets, push rods, gear-box, and flywheel. It is not necessary to remove the chain, but if this is not done *care must be taken when knocking the camshaft out* from the front that the sprocket is not allowed to fall down; this can be done by following through with a metal rod slightly smaller in diameter than the end of the camshaft.

The flywheel must be removed from the crankshaft, and the covers from both the front and rear ends of the camshaft removed. The five locating set-screws along the offside of the crankcase should be withdrawn together with the one on the crankcase top face, as these locate the camshaft bearings.

Next, remove the oil pump and the vertical-drive shaft which is driven from the front end of the camshaft. To do this, remove the cover on the top of the crankcase and also the cover plate on the side. Remove the oil pump, unscrew the nut from the top of the vertical drive, and knock on end of spindle, so that it is driven out of the spiral gear. The gear can then be removed through the side cover. Next, unscrew the nut securing the camshaft sprocket and outer ball-race and knock the camshaft back carefully, towards the rear. *The cams will bear against the five bearings* and will force them out of the crankcase, when, being split, they can be withdrawn from the shaft and the latter withdrawn from the rear end.

Replacing the Cylinder Head

The method employed is to lower the cylinder head carefully over the studs until it rests on the jack nuts. These hold it about $\frac{1}{2}$ in. above the cylinder. Keeping the head parallel with the cylinder, bring the two together by giving each jack nut alternately a few turns with the spanner. Tighten the head down carefully, in order to avoid distortion, giving each nut a few turns at a time until they are uniformly tight. The nuts should be tightened in the numerical order shown in Fig. 89. Always tighten up again after the engine has been run and whilst it is still warm. The push rods should now be replaced, making sure that the lower ends are engaging properly with the tappets. Replace the rocker assembly, connect up water and exhaust pipes, cylinder-head cover, and injector-fuel pipes.

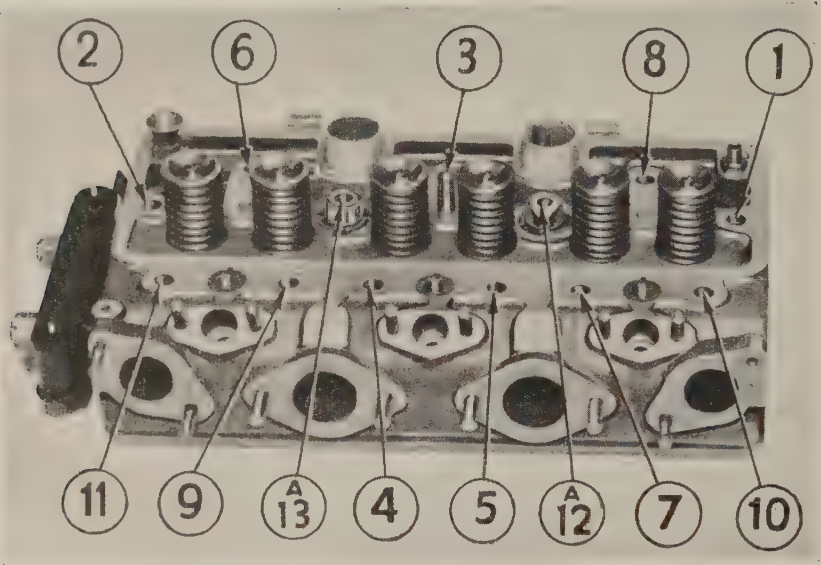


Fig. 89.—Replacing A.E.C. Cylinder Head.

It should be noted that the cylinder-head cover also forms the air-intake pipe, so that *particular care should be taken when running the engine without the cover* to see that nothing is dropped into the vertical air-intake ports in the cylinder head.

Removal of Car Body from Chassis

When it is necessary to remove a car body from its chassis in the event of major body repairs due to an accident or when the engine and transmission, steering, suspension, and braking systems require a major overhaul, it is necessary, first, to make a careful examination of the chassis and body or to obtain the manufacturer's instructions for locating and removing the holding-down bolts.

Before the body can be removed all external connections of the body to the various chassis members, e.g. steering wheel, trafficator control, electric cables, instrument connections on dashboard, etc., should be disconnected. A close examination of every part of the body should be made after disconnecting the various attachments and holding-down bolts to ensure that nothing has been overlooked.

It is not possible, nor desirable, to describe the methods of removing various makes of car bodies from their chassis, but a typical example of the procedure adopted in the case of a popular modern car, namely the Austin A40 (Fig. 90), will be described in detail.

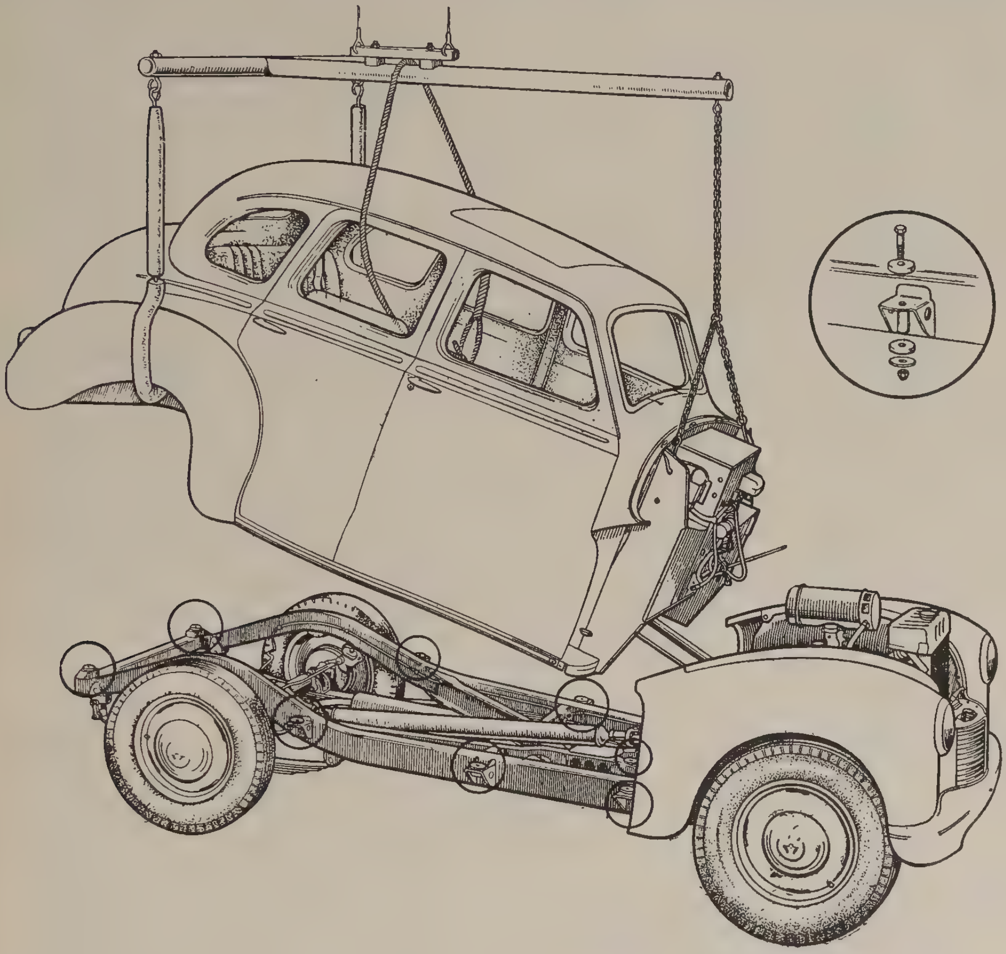


Fig. 90.—Removing Austin A40 Body from Chassis.

To remove the body the following operations must first be effected:

(*a*) Remove the steering wheel and trafficator control and then the fascia and fascia tray to steering-column brackets. The latter bracket also releases the pistol-grip handbrake.

(*b*) Disconnect the lighting and ignition wires at their nearest convenient connections between the body and the chassis, and disconnect the battery earthing and starter cables.

(*c*) Disconnect the oil-gauge pipe and the speedometer cable.

(*d*) Disconnect the carburettor choke and throttle controls.

(*e*) Disconnect the fuel-tank pipe at the tank and the tank-gauge cable at its terminal on the tank.

(*f*) Release the pistol-grip handbrake at its connection to the chassis lever.

(*g*) Drain the cooling system and remove the water pipes leading to the heater.

(*h*) Remove the bonnet top.

(*i*) Detach the front wing assembly bolts from their locating points to the body.

(*j*) Unscrew the heads of the brake and clutch pedals and the two screws holding the body plate in position round pedal stalks.

(*k*) Unscrew the ten screws holding the gearbox rubber covering in position; unscrew the gear lever knob and lift off the rubber cover.

The body can now be lifted clear of the chassis when the ten body and chassis bolts are removed. The bolts are inserted from inside the body, and there is a rubber bush between the body and the chassis at each mounting point. A further rubber bush and plain washer is fitted between the self-locking securing nut and the underside of the chassis.

The two securing bolts at the rear have an additional plain washer under the bolt head.

The sling used to hoist the body should be designed to lift the rear of the body first, as this helps the body to clear the steering column.

Replacing the body is an exact reversal of the removal instructions.

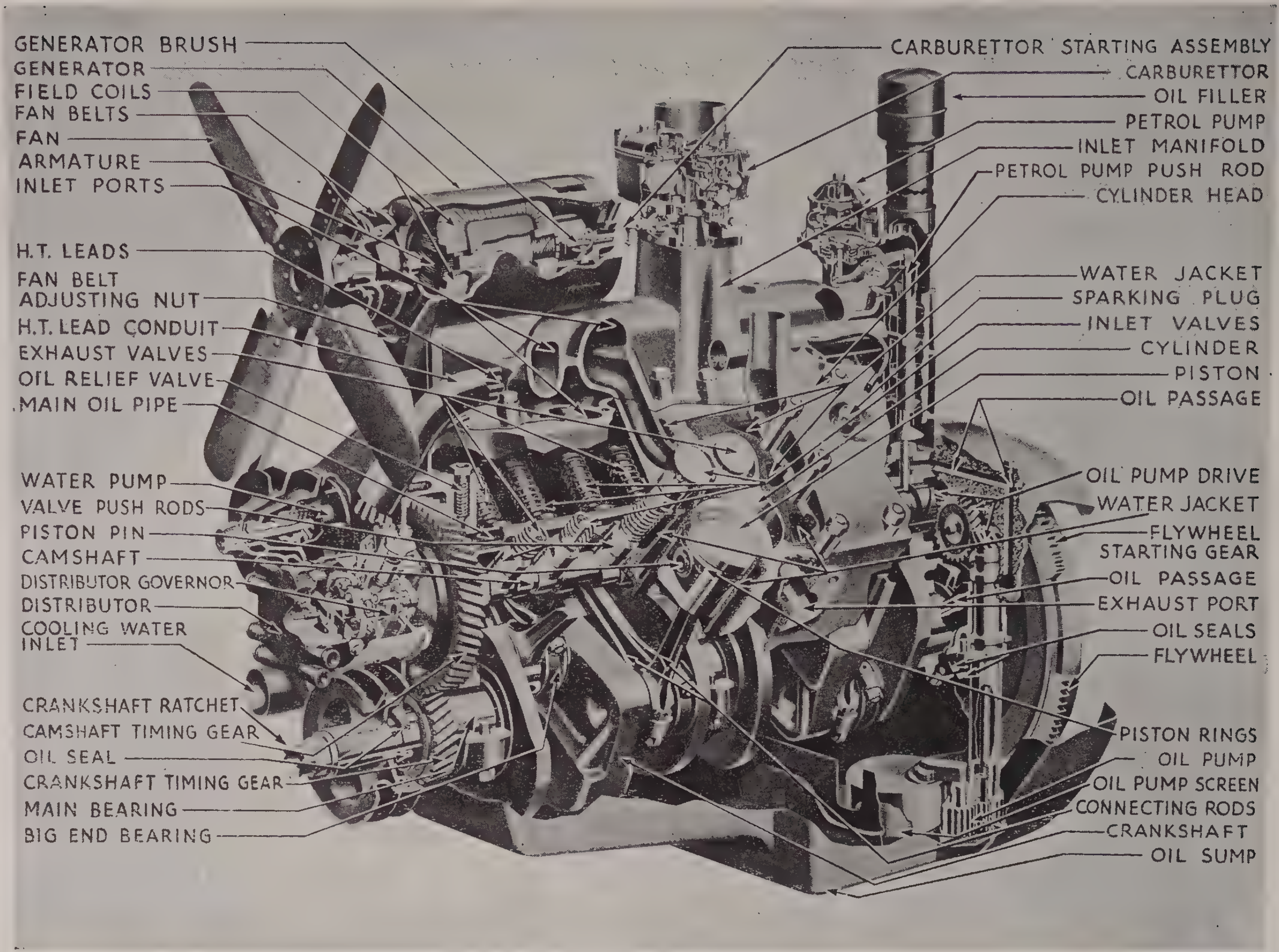
Some Hints on Dismantling Motor Vehicles

The adoption of a proper procedure when dismantling a motor vehicle or chassis component will not only save a good deal of time when reassembling the parts, but will also obviate the inconvenience occasioned by the loss of any of the parts; in this respect, the loss of a single bolt or nut—especially if it is not a standard article—may often cause a vexatious delay.

Experienced engineers have for long adopted certain excellent methods when dismantling engines and machinery, and the motor mechanic cannot do better than follow the teachings of a very much older trade than his own.

When a car has to be completely overhauled, the body is unbolted or otherwise detached from the chassis frame and lifted off, as explained previously. Next, the larger components are disconnected, commencing with the radiator and following with the engine, gearbox, universals, propeller-shaft, and back axle. This is usually fairly straightforward work if one has the necessary means for hoisting the parts, jacking and blocking up the chassis frame, and handling the parts.

An important point to remember is that of *replacing all bolts, nuts, and*



THE FORD PILOT V-8 EIGHT-CYLINDER ENGINE, SHOWING PRINCIPAL PARTS.

pins immediately a chassis part is detached. Suppose, for instance, the engine is disconnected from the chassis frame and engine bearers or plates. As soon as the job is started each of the anchoring bolts and nuts should be marked (by one or other of the methods described later), and the engine, crankcase, or bearer casings similarly marked, in order that each part may be identified with its respective position. As soon as the engine is hoisted clear of the frame, the *bolts and nuts should be replaced* in their original positions in the frame.

It is a good procedure to clean each bolt, nut, washer, stud, or pin, to clear the threads, remove any burrs, and to see that the nuts run down the threads freely. This will save a good deal of trouble when reassembling the parts, for there is nothing more exasperating than to have to screw down a tight nut in an awkward position on the car—very often the bolt head must also be held all the time.

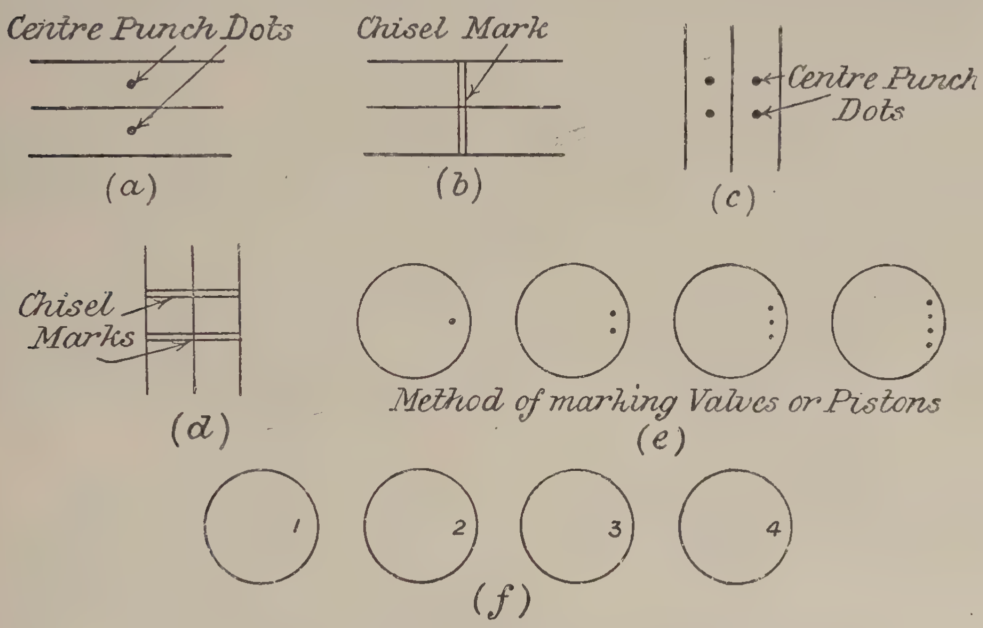


Fig. 91.—Illustrating Methods of Marking Metal Parts before Dismantling.

Next, after the detachment of complete components from the chassis is the *dismantling of each component* into its various parts.

It is as well to have one or two wooden boxes of different sizes handy, one for the larger parts and another for smaller items, such as screws, bolts, nuts, washers, pins, split pins, etc. In the case of certain packings or liners, such as those used for the cylinder head, inlet and exhaust manifolds, it is advisable to hang these, after cleaning, on a nail out of harm's way.

The corresponding parts of the component should be marked before attempting to dismantle them. In many cases cover-plates, flanges, and caps will only reassemble in one position, so that much time will be saved if the parts are marked beforehand.

Fig. 91 illustrates the conventional methods of marking engineering parts for identification purposes. If there are only two components, as shown in (*a*) and (*b*), a centre-punch mark on each part, or a single chisel mark, will be quite satisfactory. If there are more than two components of the same type—say, three similar flanges—the method shown in (*c*), (*d*), and (*e*) will be found convenient.

As an example, the poppet valves of a four-cylinder engine are usually identical in design, but each has been " worked " or " bedded " into its appropriate seating and guide; its length is also correct for its tappet height and adjustment. The valves should be marked, either with centre-punch dots, beginning with No. 1 nearest the radiator, and marking each valve consecutively with 1, 2, 3, 4, 5, 6, 7, and 8 dots, or, better still, with actual metal figure stamps.

In some cases there may be several cars of the same make under repair, and here the importance of labelling the parts of each car in some distinctive manner will be apparent. Further, *after an engine or chassis has been dismantled* and cleaned, it is given a *very careful examination* for wear, fractures, and other defects. As each part is inspected and any defect detected, it should be labelled (in this case with a linen tag), stating the nature of the defect, the repair decided upon, the make of car, and part.

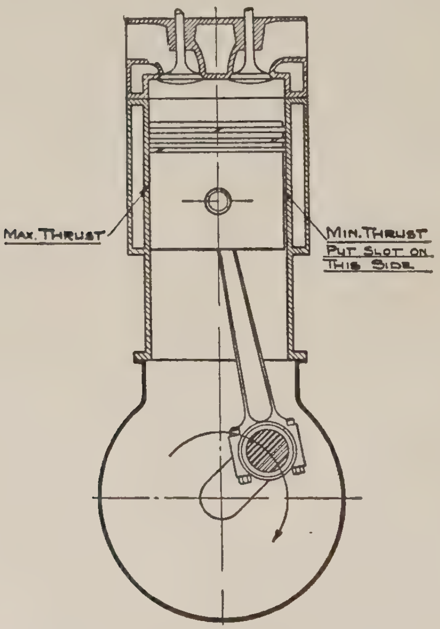


Fig. 91A.—The Thrust Faces of a Piston.

Marking the Pistons

The pistons in modern engines are numbered and in many cases have a distinguishing letter, e.g. A, B, or C, to denote the selective fits of the pistons. Usually, the pistons of a 4-, 6-, or 8-cylinder in-line engine are numbered from No. 1, commencing at the radiator end. If, however, the numbers are not found on any set of pistons—and this may only be in the case of earlier makes—they should be punched or stamped on the piston crowns, near one side of the piston, in each case. The reason for this is that in most engines the pistons must be replaced the same way round.

In the case of split-skirt pistons the split which extends down one of the thrust faces must be on the minimum thrust side, so that the piston markings of identification should ensure that this is effected. Fig. 91A shows the maximum and minimum thrust-free sides of the piston in relation to the direction of rotation. In this connection it is useful to remember that in the normal British front-engine car the minimum thrust face of each piston is on the near-side of the car, i.e. on the right side as one faces the radiator from the front end.

The Connecting Rods

It is equally important to check that the connecting rod is marked with corresponding figures or letters on either side of the split big-end bearing. This marking should be the same side of the rod, i.e. near-side or off-side, for all of them, so that when replacing the rods they will all go back in their original positions. This is an important point to remember since there are now several designs of non-symmetrical connecting rods, notably those having a clamping method for the small-end to hold the gudgeon pin securely. There is also the increasingly popular type of big-end, in which the line of *separation or "split" of the two halves* of the bearing is at *an angle to the usual symmetrical position.* It may be mentioned that when replacing this type of connecting rod the correct position is with the upper bearing on the maximum piston thrust side of the cylinder. The position is correct if one looks at the engine or cylinder from the front of the car, so that the upper end of the split big-end bearing will be on the near-side of the car. The same directions apply also to the Standard Vanguard connecting rods and, indeed, to all similar unsymmetrical ones.

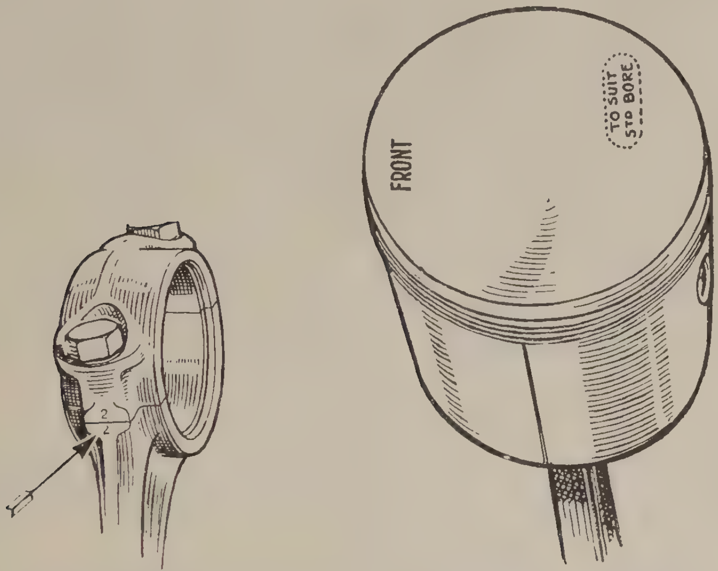


Fig. 92.—Method of marking Morris Oxford, Series MO, Connecting Rods and Pistons. The front of the Piston is clearly marked on the Crown, which also has Markings to indicate its size.

In the case of certain post-war Austin engines, notably the 12-h.p.

16-h.p., A40, etc., the connecting rods have special positions which differ in arrangement along the crankshaft. Thus in the case of the 12-h.p. and 16-h.p. engines the small-end pinchbolts are on opposite sides from No. 1 to No. 4 cylinders, i.e. the positions alternate, as shown in Fig. 93. The connecting rods are numbered 1–4 starting from the front end, and this numbering is stamped on both halves of the big-end bearing, *the numbers being stamped on the side facing the camshaft when assembled.*

For the A40 engine the big-end portion of each connecting rod is offset in relation to the webs, as shown in Fig. 94. When assembling the rods the offset portions should be arranged as shown. It will be noted that the small, end pinchbolts are all on the same side, namely the near-side of the engine.

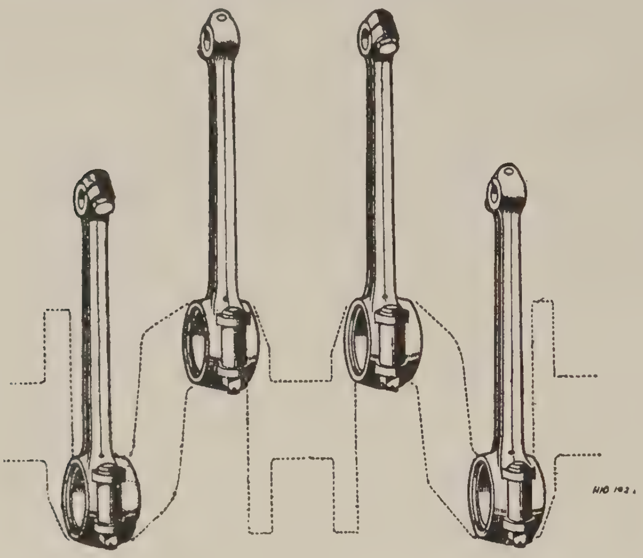


Fig. 93.—Connecting-rod Arrangement.

The Valve-timing Gear

Although in all modern car engines the timing gears or sprockets are marked in such a way that when replaced the valve timing will be correct there are many earlier and special engines in which no markings are given. It is therefore advisable before dismantling the timing gears or drives of such engines to first clean and then inspect the timing gears for any markings. If there are no markings, the actual valve timing should be noted down, using the top dead centre of No. 1 piston as a reference, and noting the distance on the flywheel from this position at which No. 1 inlet valve opens. This subject is dealt with more fully in a later chapter.

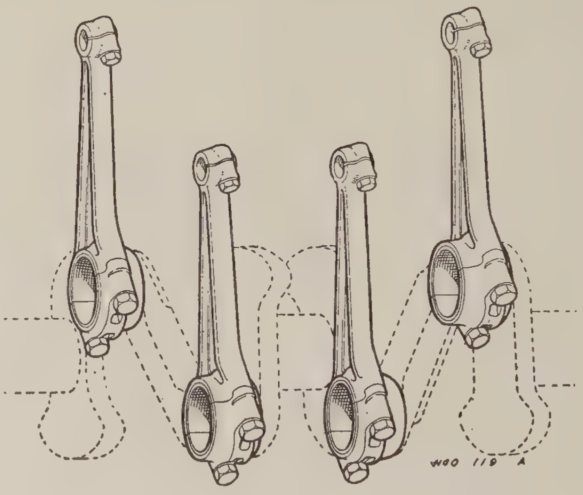


Fig 94.—The Austin A40 Connecting-rod Arrangement.

ENGINE FAULTS AND HOW TO TRACE THEM

- **ENGINE REFUSES TO START**
  - GOOD SPARK AT PLUGS INDICATES CARBURETTOR TROUBLE CAUSE
    - PETROL TAP SHUT
      - NO PETROL SUPPLY
    - PETROL TAP OPEN
      - CHOKED PETROL FILTER
      - AIR LOCK IN PETROL PIPE
      - GAUZE IN FILTER CLEAN, AND PIPE CLEAR
        - WATER IN BASE OF JET
        - DIRT IN JET ORIFICE
        - NEEDLE VALVE STICKING
        - THROTTLE TOO FAR OPEN
        - THROTTLE CONTROL DISCONNECTED
        - TOO MUCH AIR
        - PILOT JET CHOKED
  - WILL NOT FIRE WHEN PETROL INJECTED INTO CYLINDER HEADS INDICATES IGNITION TROUBLE
    - NO SPARK AT PLUGS
      - SPARK AT TERMINAL
        - PLUG DEFECTIVE
        - SOOTED INSULATION
        - BROKEN INSULATION
        - POINTS BRIDGED BY OIL OR DIRT
    - MAGNETO IGNITION
      - NO SPARK AT TERMINAL
        - CONTACT BREAKER ARM STICKING
        - CONTACT BREAKER ARM FREE
          - CONTACT POINTS DIRTY
          - WRONG GAP
          - DIRTY DISTRIBUTOR
          - BROKEN BRUSHES IN MAGNETO
          - MAGNETO SWITCH WRONG POSITION
          - SERIOUS DEFECT IN MAGNETO
    - COIL IGNITION
      - NO SPARK AT TERMINAL
        - CONTACT BREAKER ARM STICKING
        - CONTACT BREAKER ARM FREE
          - PLATINUM POINTS DIRTY
          - WRONG GAP
          - DISTRIBUTOR DIRTY
          - BROKEN BRUSH
          - BATTERY RUN DOWN
          - SWITCH OFF
          - COIL SHORTED INSIDE
          - ENGINE COUPLING DISCONNECTED

- **ENGINE STOPS**
  - PETROL RUN OUT
  - PETROL SUPPLY CORRECT
    - NO SPARK AT PLUG POINTS
      - MAGNETO OR
        - DEFECTIVE PLUG
        - INSULATION SOOTED
        - PLUG POINTS OILED
        - IGNITION TIMING SLIPPED
        - FAULTY H.T. CABLES
      - COIL IGNITION
        - CONTACT BREAKER STICKING
        - CONTACT BREAKER ARM FREE
          - DIRTY CONTACTS
          - BROKEN BRUSHES
          - CONDENSER BROKEN DOWN
          - WATER IN MAGNETO
          - INTERNAL SHORTING
          - COUPLING TO ENGINE DISCONNECTED
    - SPARK AT PLUG POINTS
      - LOSS OF COMPRESSION
        - VALVE STICKING
        - BROKEN VALVE
        - STRETCHED VALVE
        - BROKEN SPRING
        - INSUFFICIENT LUBRICATION
        - BROKEN PISTON OR CONNECTING ROD
        - PISTON RINGS GUMMED UP
      - COMPRESSION
        - CARBURETTOR WORKING
          - BROKEN VALVE, REMAINING ON SEATING
          - CONTROLS OUT OF ORDER
          - STRIPPED TIMING GEARS
          - BAD AIR LEAK AT INLET OR CARBURETTOR JOINT
        - CARBURETTOR NOT WORKING
          - PETROL SUPPLY STOPPED (CHOKED JET, DIRTY FILTER, BLOCKED PIPE, BROKEN PIPE OR UNION, AIR LOCK)
          - PUNCTURED FLOAT
          - NEEDLE (FLOAT) NOT FREE
          - CARBURETTOR MECHANISM NOT FUNCTIONING
          - WATER IN CARBURETTOR

- **ENGINE RUNS UNSATISFACTORILY**
  - MISFIRES
    - INTERMITTENT SPARKING
      - PLUG INSULATION SOOTED
      - OIL ON PLUG POINTS
      - DIRTY CONTACT BREAKER POINTS
      - BROKEN CARBON BRUSHES
      - FAULTY CABLE INSULATION
    - REGULAR SPARKING
      - VALVE STICKING OR BROKEN
      - MIXTURE TOO WEAK
      - MIXTURE TOO RICH
      - WATER IN CARBURETTOR
      - PARTLY CHOKED PETROL PIPE OR FILTER
      - AIR LEAK INTO INLET PIPE
      - LEAKAGE PAST VALVE STEMS
      - NO HOLE IN PETROL TANK CAP
  - LOSS OF POWER
    - REGULAR
      - POOR COMPRESSION (WORN CYLINDER, PISTON AND VALVES)
      - THROTTLE CONTROL OUT OF ADJUSTMENT
      - SPARK TIMING INCORRECT
      - VALVE TAPPET CLEARANCE TOO MUCH OR INSUFFICIENT
      - BAD VALVE FACES
      - VALVE SPRING BROKEN OR TOO WEAK
      - INCORRECT MIXTURE ADJUSTMENT OF CARBURETTOR
      - CHOKED SILENCER
      - VALVE TIMING WRONG
      - GEAR TOO HIGH
      - EXCESSIVE CARBON DEPOSIT
      - OIL SUPPLY DEFICIENT
      - VALVE STICKING IN GUIDE REGULARLY
      - CYLINDER HEAD JOINT LEAKING
    - IRREGULAR
      - VALVE STICKING OCCASIONALLY
      - CARBURETTOR REGULATION FAULTY
      - PETROL SUPPLY INTERMITTENT
      - BRAKES ADJUSTED TOO CLOSE
  - ENGINE RUNS TOO HOT AND KNOCKS
    - EXCESSIVE CARBON DEPOSIT
    - OBSTRUCTED RADIATOR
    - INSUFFICIENT WATER IN COOLING SYSTEM
    - INSUFFICIENT LUBRICATION
    - SPARK TOO FAR ADVANCED
  - ENGINE RUNS AT CORRECT TEMPERATURE BUT KNOCKS
    - SPARK TOO FAR ADVANCED
    - LOOSE CONNECTING ROD BEARINGS
    - EXCESSIVE BACKLASH IN ENGINE GEARS
  - FIRES OCCASIONALLY ONLY
    - SPARK INTERMITTENT
      - SOOTED OR OILED PLUGS
      - DIRTY CONTACT BREAKER POINTS
      - BAD INSULATION
      - DIRTY DISTRIBUTOR
    - SPARK REGULAR AT PLUGS
      - MIXTURE TOO RICH
      - MIXTURE TOO WEAK
      - CHOKED PETROL FEED
      - WATER IN CARBURETTOR
      - VALVE STICKING
  - POOR HILL-CLIMBING AND LOW MAXIMUM SPEED ON LEVEL
    - ENGINE REQUIRES OVERHAUL
    - EXCESSIVE CARBON DEPOSIT
    - ENGINE IN GOOD MECHANICAL CONDITION AND CLEAN
      - TOO HIGH A GEAR (HILLS
      - MIXTURE TOO WEAK
      - IGNITION TOO FAR RETARDED
      - IGNITION TOO FAR ADVANCED
      - CLUTCH SLIPPING
      - TYRES UNDER-INFLATED
      - BRAKE ON

ENGINE FAULTS AND HOW TO TRACE THEM

HOW TO USE THE CHART

This Chart has been carefully arranged, with the object of indicating to the motor engine user, in a most expeditious manner, the cause of any trouble experienced. For this purpose, the alternative possible, or likely, causes have been grouped into three main classes, namely : (1) *The Engine Refuses to Start ;* (2) *The Engine Stops ; and* (3) *The Engine Runs Unsatisfactorily. It is not a difficult matter, even for the novice, to ascertain into which class the engine trouble belongs. The next step is to find out whether it is the ignition or carburation at fault. The sub-classification of major faults, or causes, will show which of these items is concerned. Then by a process of elimination, step by step, using the information given in the Chart, the actual cause may be found. Having found the cause of the trouble, the reader will find the Index of these volumes a useful help in looking up the item concerned, with the object of remedying same.*

CHAPTER 5

CLEANING THE COMPONENTS—DECARBONISING

Assuming that the component or components of a car have been dismantled, and that all bolts, nuts, and similar items have been replaced, and corresponding parts identified, the next important item, before inspection, is to clean them thoroughly. A film of oil or a few particles of dirt will mask the wear in pins and bearings; moreover, it is always desirable to work on clean parts.

The mechanic or engineer of the small garage will not, of course, be so well provided with cleaning means as the larger garages, but, nevertheless, with a little patience and the ordinary cleaning materials he can make a thoroughly good job. Apart from a good supply of cleaning rags and cloths—thick heavy ones for the dirtiest jobs, and soft ones, such as sponge or mutton-cloth, for the final cleaning operations—it is necessary to have some sort of a cleaning tray or bath.

The enterprising mechanic will find it better to make a cleaning tray out of a sheet of tin, the seams being well soldered and lapped so as to be oil-tight.

An ordinary enamel bowl of the domestic type or a large biscuit tin will serve the purpose; whilst for cleaning small parts, such as screws, nuts, washers, and springs, any ordinary tin which is oil-tight will serve.

Paraffin as a Cleaning Agent

Where no other special cleaning plant exists a good expedient is to *use paraffin oil* for degreasing and cleaning dirt off motor components, since this liquid will dissolve grease and dislodge dirt readily. If a wire or bristle brush is used to get rid of accumulated dirt in awkward places, the cleaning process can be expedited. For small parts an ordinary toothbrush will be found very useful.

The paraffin can be used over and over again if it is filtered through a fine gauze, or is allowed to stand until all solid matter has sunk to the bottom, when the clear liquid can be decanted.

It may be noted that certain garage degreasing and cleaning plants employ paraffin as the liquid agent.

Caustic Soda Solution

Alkaline solutions, such as soda carbonate (ordinary domestic washing soda), or the stronger caustic soda ones, made up as saturated solutions with water are strong degreasing liquids, and have been widely used in the past for cleaning dirty steel and brass components. They are not generally advised, however, for aluminium-alloy parts since there is a strong chemical action, the solution tending to eat away the metal if left in contact for appreciable periods.

A quick immersion in either of these alkaline (heated) solutions followed by a rinsing in clean water will get rid of grease and dirt on aluminium components without allowing the solution time to act chemically upon the metal.

There are degreasing plants of the immersion kind that use alkaline solutions. It must be added, however, that strong alkaline solutions have a deleterious effect upon the hands, and contact with such solutions should be avoided. Dermatitis or skin disease may follow frequent wetting of the hands with alkaline solutions, even if in the weak condition.

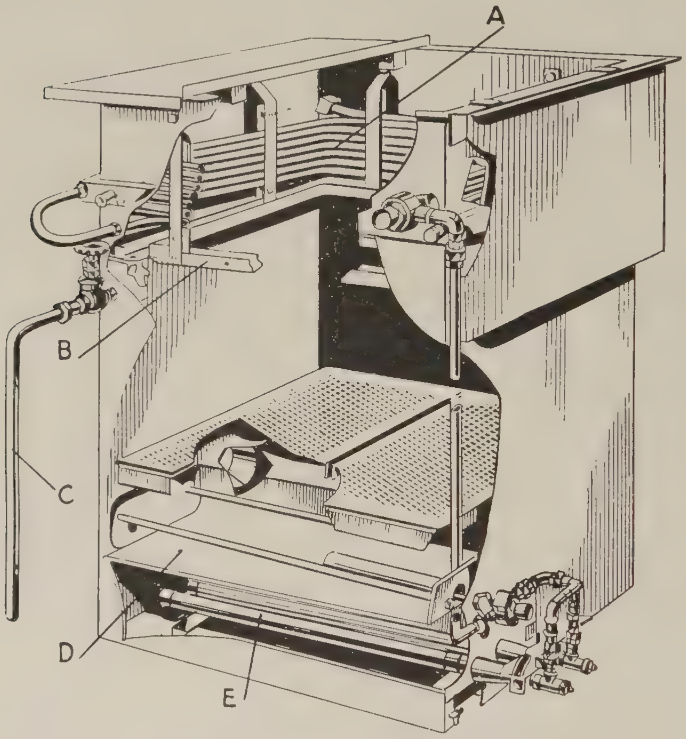


Fig. 95.—The I.C.I. Chemical Degreasing Apparatus. A—Cooling Coils. B—Distillate Trough. C—Pipe for Recovered Solvent. D—Liquid Sump. E—Gas Burners.

Degreasing Plant

There are three principal methods employed in automobile and general mechanical engineering degreasing plant, namely: (1) the vapour process; (2) the paraffin method; and (3) the alkaline solution one.

The vapour-cleaning method is based upon the degreasing action of the chemical solution known as trichlorethylene, and also its vapour.

Fig. 95 illustrates the I.C.I. degreasing plant[1] which is based on this principle; various alternative designs of such plant are available.

The trichlorethylene vapour used in this plant is one of the most powerful grease solvents known; moreover, it is cheap and non-inflammable. The parts to be cleaned are placed on the grid shown, and the vapour from the heated solvent passes upwards through the spaces between them. Upon reaching the cooling coils A the vapour is condensed and the liquid is returned to the base reservoir ready for use again.

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[1] Imperial Chemical Industries' Ltd., London S.W.1.

After the parts are removed from the cleaning trays they are perfectly clean and dry, being in excellent condition for examination.

The paraffin method of cleaning, previously referred to as a washing process, is improved upon in modern degreasing plant such as the Harvey Frost, Mann Egerton, and Laycock designs. In these use is made of a pressure-operated paraffin spray which is directed on to the dirty components placed in a perforated metal or wire tray. The dirt and grease are readily removed, and the dirty paraffin is drained through a filter into a reservoir at the base of the plant, where it is ready for use again.

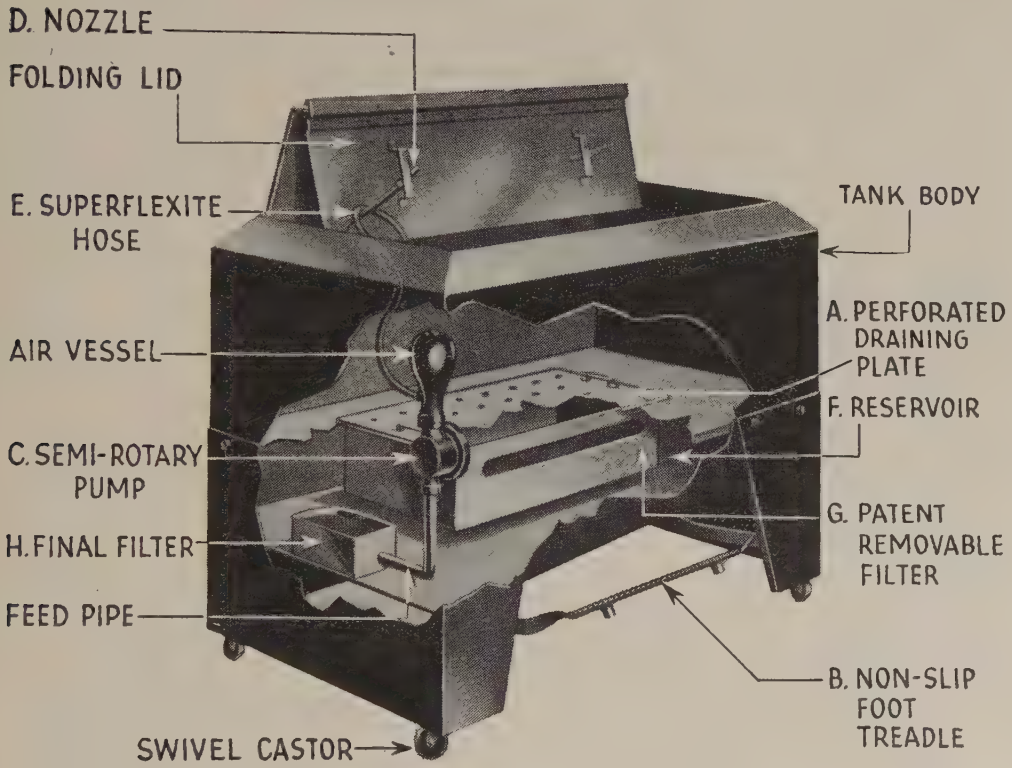

Fig. 96.—The H.F. Paraffin Cleansing Tank.

The pressure is obtained in some cases by a hand-, foot- or electrically-operated pump of the semi-rotary pattern. The smaller foot-operated pump leaves the hands free to manipulate the paraffin sprayer.

Fig. 96 illustrates the Harvey Frost (H.F.) paraffin cleansing tank which is of the foot-operated semi-rotary pump pattern. The various parts of the plant are annotated in this part cut-away illustration. The parts to be cleaned are placed on the perforated draining plate (A) or in a small parts container provided. By working the non-slip foot treadle (B) they are then sprayed with paraffin under pressure from the pump (C) through the nozzle (D). The nozzle is connected to the pump by means of a length of special composition (Superflexit) hose which cannot leak or corrode. The paraffin drains into the reservoir (F) through the special filter (G) which retains the sediment and is easily removed for cleaning. The cleaned paraffin is returned by the pump through a second filter (H) and can then be used over and over again. In the power-driven pump model of this plant a $\frac{1}{4}$-h.p. electric motor replaces the foot treadle. To guard against any splashing a detachable folding lid is provided.

An additional accessory is a revolving spray that makes the cleansing tank practically automatic in action. It has one central and four revolving jets, and the whole of the components placed in the perforated metal tray or shelf can be effectively treated in a single operation. The paraffin, under pressure, in leaving the jets provides the means for their rotation on the well-known jet-propulsion principle.

The smallest H.F. tank (foot-operated pump) measures 3 ft. × 2 ft. × 2 ft. and can hold parts up to 10 cwt. for a single cleaning operation. The electrically operated pump model measures 5 ft. × 2 ft. 6 in. × 2 ft., and takes up to 13 cwt. of components which are cleaned in a single operation.

Fig. 97 illustrates the Laycock air-pressure paraffin cleansing tank, which uses a jet of compressed air to force the paraffin through the delivery pipe and nozzle at high or low pressure as desired. The air pressure required is between 30 and 200 lb. per sq. in. About 7 gallons of paraffin

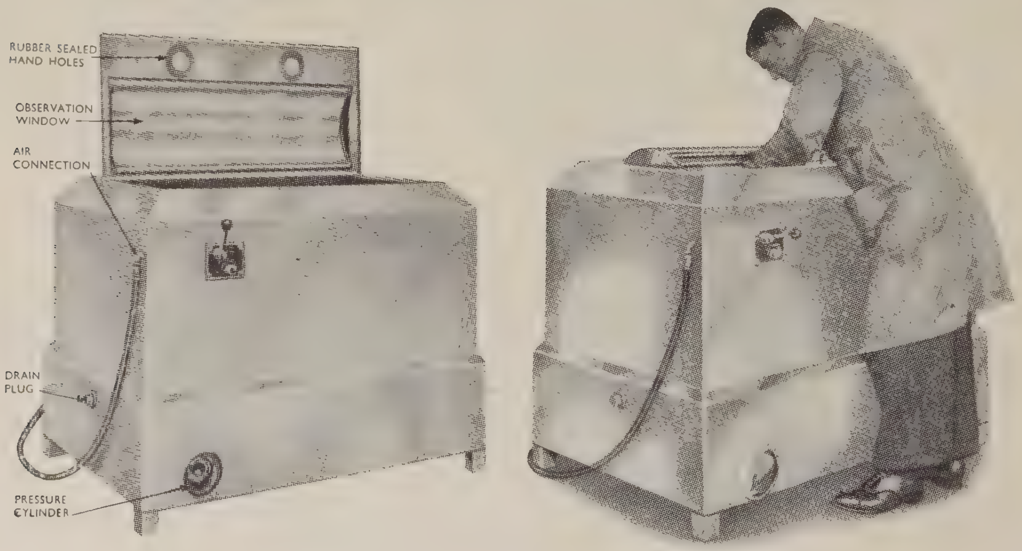

Fig. 97.—The Laycock Air-pressure Paraffin Cleansing Tank.

are provided in the reservoir. Rubber-sealed hand holes are arranged in the lid for the operator, and a Perspex observation window enables the work in hand to be viewed during the process of cleaning. When the parts have been cleaned the operator can switch over to compressed air only, for the purpose of drying the components.

The alkaline method of degreasing uses the immersion tank arrangement, in which small parts are placed by hand in the cleaning tray and large parts, such as cylinder blocks, are lowered by means of a gantry hoist or Jackrane, for total immersion in the solution.

The Laycock air-pressure cleaning tank is equally suited for the use of alkaline detergent solutions, and is also employed for this method of degreasing motor parts.

The M.E. plant illustrated in Fig. 98 is a neat and compact degreasing plant with a capacity suitable for a continuous flow of work, as when engine reconditioning necessitates constant cleaning of the parts.

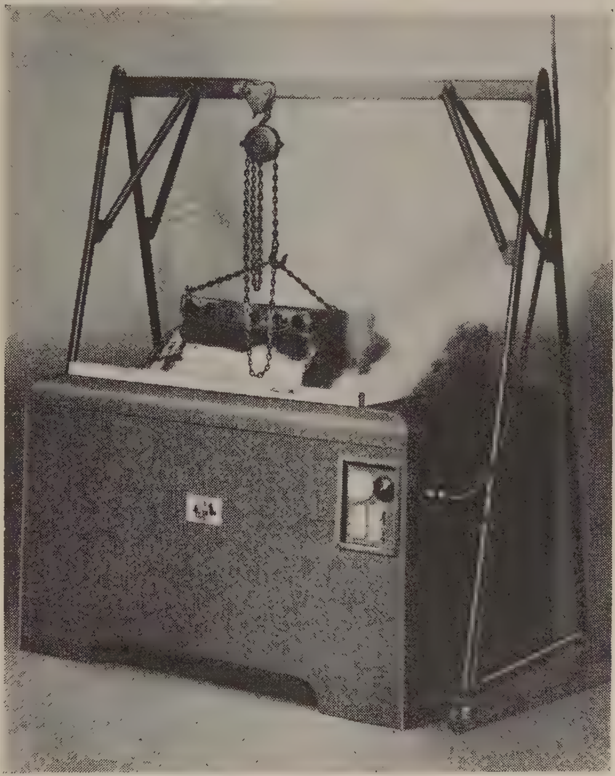

Fig. 98.—The M.E. Degreasing Tank, with Gantry for raising and lowering Heavy Parts.

The method used is to heat the detergent solution by means of two immersion tube heaters of 3 kW. capacity, with thermostatic controls for the temperature. The inner tank, measuring 52 in. × 30 in. × 30 in., has a capacity of 130 gallons. It is first filled with this amount of clean water and the heaters switched on; about $7\frac{1}{2}$ hours are required to attain the operating temperature. The detergent—usually in the form of crystals—is then added and when dissolved the parts to be cleaned are inserted in their baskets or trays, the lid closed, and the compressed-air supply for agitating the liquid adjusted to the required operating pressure, which is shown by the pressure gauge on the front of the tank (Fig. 98). As the inner tank is well lagged it retains its heat for a relatively long period after the power is switched off.

The alkaline detergent employed is suitable for iron, steel, copper, and brass parts for long periods, but aluminium and magnesium alloys should not be immersed for longer than about five minutes, after which they should be rinsed well in clean water.

In another type of alkaline immersion degreasing plant the solution is heated up to the boiling-point of water (212° F.), and compressed air is used for agitating the solution. In the Weaver gas-heated immersion tank the compressed air is preheated, and a thermostat is employed to control the temperature of the solution. Steam jets have been used for cleaning dirty motor parts, as in the case of the Weaver high-pressure steam cleaning plant.

Preliminary Cleaning

When cleaning dirty motor parts it will be found that the most difficult matter to remove is the sticky mixture of oil and grit or dirt which adheres to the exterior surfaces—more particularly to the outside of the crankcase, sump, and gearbox. A little preliminary scraping with a piece of hard wood or copper, shaped in the form of a scraper or chisel, will relieve the final cleaning process in the paraffin or caustic soda bath and prevent a good deal of sediment forming in the baths themselves, so that less frequent cleaning-out will be needed.

Care of the Hands

It may not be out of place to add one or two remarks for the benefit of those amateur mechanics and others normally engaged in cleaner occupations who occasionally undertake dirty work in connection with motor vehicles. The usual result of working on the chassis parts is to leave the finger-nails dirty, both under the tops and around the edges, with a black, greasy deposit. This may be obviated by first filling the nails with yellow soap and smearing the nail edges with the same material. A special preparation of an antiseptic nature for giving the nails and the hands a preliminary smearing is put up in leaden tubes. This antiseptic cream (known as "Peldo") evaporates, leaving a soluble skin on the hands. When the hands are finally washed with ordinary soap and cold water all dirt disappears.

To clean the hands if very dirty, a preliminary washing should be given in petrol or paraffin; this removes most of the grease and dirt. Special soaps for the hands include "Gre-solvent" and "Chemico" compounds; these are quite efficacious. The use of powdered pumice for cleaning very dirty hands is excellent. Sand and sawdust are also useful in an emergency for loosening the dirt.

Carbon Deposit and its Removal

One of the most important, and most frequent, operations in the care of automobile engines is that of decarbonising the cylinders—that is, in getting rid of the carbonaceous layers which in the course of time cover the non-bearing surfaces of the combustion chamber, valve heads, and piston tops.

After a modern engine has been running for about 4,000 to 6,000 miles the cylinders should be decarbonised, otherwise the engine will not only work less efficiently but there will be an increasing tendency towards detonation and pre-ignition, and a greater likelihood of premature wear in the pistons and cylinder walls. It should subsequently be decarbonised every 5,000 miles or so. In the case of certain modern new engines, decarbonising is recommended after the first 2,000 to 3,000 miles.

Nature of Carbon Deposit

It must be remembered that a large percentage of the "carbon" deposit in automobile engines consists of extremely hard siliceous material from the road grit and dust drawn into the cylinder from the outside air, *via* the carburettor. In some cases as much as 60 per cent. of the cylinder deposit has, on analysis, been found to be of a siliceous nature, the balance being carbon derived from the lubricating oil and a small amount of iron from the cylinder material. The silicon content of this deposit represents an abrasive material which is the cause of all of the cylinder and piston wear occurring in the engine, and if the dust is excluded from the carburettor air, engines will—as tests have conclusively shown—last very much longer. In some cases the exclusion of road dust has been found to give a useful life at least four times that of the ordinary unprotected engine. The modern air cleaners greatly prolong the lives of engines.

Decarbonising Methods

The method which is employed for decarbonising any engine will depend upon the type of engine, and on whether it is desired merely to decarbonise and not to dismantle or regrind the valves. In cases where carbon collects fairly readily and requires removal after every 3,000 miles or so, it is not always necessary to regrind the valve seatings, and the quickest and most effective method of getting rid of the carbon is usually the best in such cases.

Decarbonising Detachable-head Engines

The detachable head greatly facilitates decarbonising. It is only necessary to remove the cylinder head, in the manner described elsewhere in this volume, when the whole of the combustion chamber surface is exposed, and the carbon can be scraped off with a flat scraper or broad-edge screw-driver or cold chisel; special flat scrapers are available for this purpose.

When removing carbon deposit by hand scraping or chipping, with the engine in place in the chassis, it is a good precaution to plug up all water passages, sparking-plug and stud holes to keep out the carbon, and to cover up the coachwork and wings of the car with a suitable cloth. In most cases the pistons do not quite reach the tops of the cylinder barrels when on their top dead centres, and so it is not quite such a simple operation as one might at first conjecture to remove all of the carbon. It is quite easy to scrape it from the top of the piston, but some of the powdered carbon finds its way down the piston clearance space. It can usually be removed by slightly rotating the crankshaft and wiping the cylinder two or three times. Alternatively, a grease coating around the rim of the piston will prevent this trouble.

With side-by-side valve engines of the detachable-head type, it is as well to see that the two valves of the cylinder being worked upon are closed during decarbonising operations; this will prevent carbon from becoming embedded in the seatings.

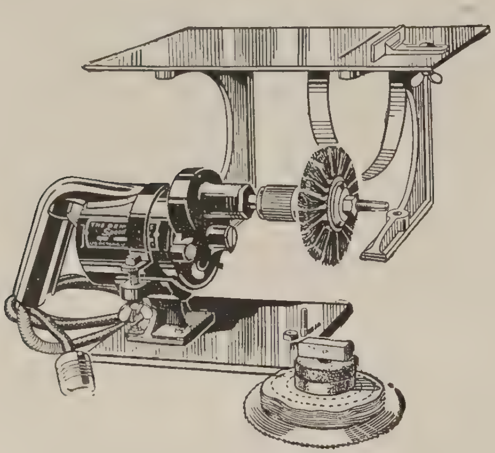

Fig. 99.—The Electric Brush used for Carbon-deposit Cleaning.

The barrels of the cylinders not being worked upon at the time should be covered or plugged with soft rag, such as old mutton cloth, to exclude carbon particles.

It will be found necessary to have one curved type of scraper for eliminating the carbon on the curved parts of the detachable head; scrapers can either be made (by grinding one corner of a flat scraper) or purchased for this purpose.

Hard Deposits.—In some cases with which the garage engineer will have to contend, the carbon deposit will be found to be much harder than in other cases (where the lubricating oil has softened it to some extent), and frequently this hard deposit will not respond to the ordinary scraper treatment or to chipping. In such cases the deposit can be softened by brushing it with ordinary petrol or, better, paraffin. Still better is it to use for this purpose one of the " chemical decarbonising liquids " sold by motor accessory firms.

The Wire-brush Method.—The garage engineer who has to decarbonise cylinders and pistons frequently will be able to save himself a good deal of time and trouble if he uses a rotating stiff wire brush for removing the carbon deposit. A portable electric motor, or electric drill such as the types shown in Figs. 101, 103 and 104, fitted with a special wire brush of the axial-bristle type, i.e. with the steel wires disposed parallel to the drill axis, is particularly convenient for the rapid removal of carbon deposit. It is only necessary to hold the revolving brush against the work and to traverse the carbon-deposited surface.

Ordinary small-diameter radial-type wire brushes are also very convenient for removing the carbon deposit from the detachable heads of cylinders, dismantled pistons, valve heads and stems, or indeed from any part which can be held over the brush. Fig. 99 shows a convenient type of universal electric tool which will be found most useful for many garage purposes; including the operation of radial and axial-type wire brushes for decarbonising purposes, the working of drills up to $\frac{1}{4}$ in., grinding of tools, sawing of soft metals, wood, ebonite, and fibre, and for operating a polishing mop and buff. It weighs but 5 lb. alone and with the saw-bench attachment 10 lb., and it can be used as a vertical drill, a suitable stand (with 5-in. table) being supplied for this purpose.

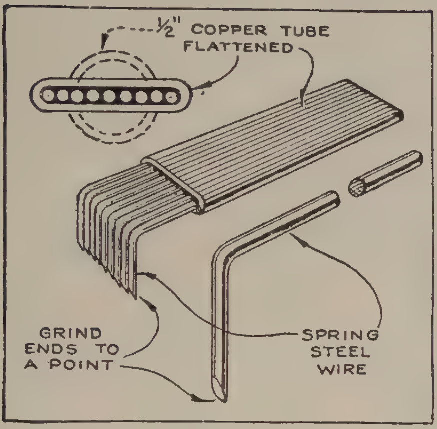

Fig. 100.—An Efficient Scraper made from Bicycle-wheel Spokes.

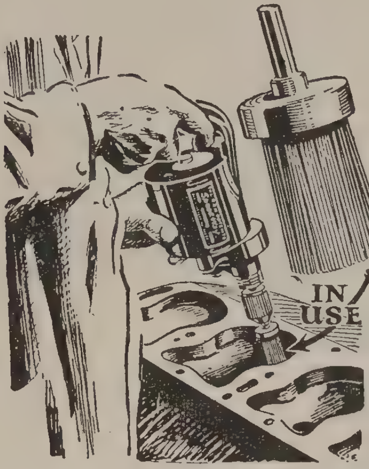

Fig. 101.—Cleaning Carbon Deposit off Cylinder Head with Electric Tool Wire Brush.

Decarbonising Tool

A useful device which can be made by the mechanic is shown in Fig. 100. This carbon scraper will cut into and quickly remove the hardest carbon deposit in the cylinder head or on the piston. To make it, take a number of pieces of spring steel wire, such as the grade known as piano wire, and cut them to a uniform length. Next take a piece of copper tubing with an inside diameter of about $\frac{1}{2}$ in., and partly flatten it. Then lay the wires side by side in the flattened end and hammer the tubing until it grips the wires. Bend the ends of the wires down, as shown, and grind them to a cutting edge. Finally, take off the cutting edges slightly on an oilstone so that they will not cut the metal of the cylinder or piston. Being flexible, this spring wire makes the tool particularly suitable for scraping carbon from curved surfaces.

Cleaning the Piston

The first operation after removing the pistons from the engine is to clean them thoroughly. This involves the scraping off of the carbon deposits on the piston head behind the rings (i.e. in the piston-ring grooves) and, what is of equal importance, inside the piston; most of the carbon deposit in the latter case will be found inside the crown. In the case of cast-iron pistons, more particularly in air-cooled engines, an appreciable amount of carbon deposit usually occurs inside the piston, and if it is not removed at intervals, the carbon may break off and drop into the crankcase. Any mixing of these particles with the lubricating oil is harmful, for the big-end and other bearings and working surfaces may wear out more rapidly.

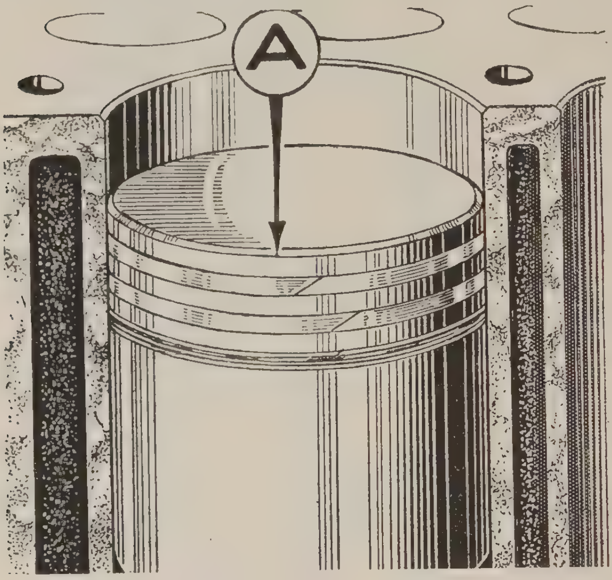

Fig. 102.—The Bevelled Edge (A) on the Austin Piston.

It is a *drawback*, in the case of modern motor-vehicle engines having detachable cylinder heads, that the insides of the pistons do not get cleaned at all frequently, for the removal of the cylinder heads only enables the piston tops to be cleaned. When the earlier solid-ended cylinders were decarbonised, the pistons were fully exposed and could be cleaned, both inside and out.

There is little to be said concerning the actual method of removing the carbon deposits. The wire brush rotated by a small electric motor is very suitable for cleaning the piston head, and a good deal of the carbon inside the cylinder can be loosened by means of a rotating-axial-type wire brush; otherwise a flat-ended scraper must be used, and, it should be added, with patience.

When scraping the carbon deposit from the heads of aluminium alloy pistons when the latter are in position in their cylinders, it is now the recommended practice to leave a narrow ring of carbon unscraped around the periphery of each piston (*vide* Fig. 117). This ensures that the oil will not get past the piston so readily. Fig. 102 shows the piston of the Austin 12-h.p. post-war engine having a bevelled edge to the crown at A. The carbon is not scraped from this edge during decarbonising; tests have shown a lower oil consumption than when the edge is cleaned bright.

If the piston is soaked for a time in paraffin the carbon deposit will be softened to some extent, and thus rendered much easier to remove. We have also found that an application of a chemical carbon remover greatly facilitates the loosening and removal of carbon deposit from pistons, sparking plugs, and valves. If the article can be immersed in, or saturated with, this liquid in an enclosed vessel—for the liquid usually vaporises—it will be found more effective to clean afterwards.

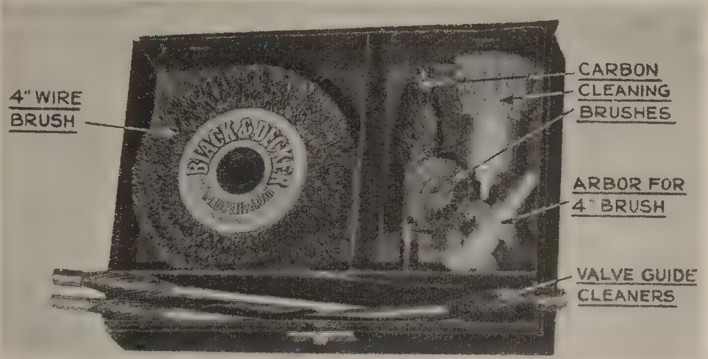

Fig. 103.—A Set of Carbon-cleaning Brushes for Use with Electric Drill Motor.

There is, however, one *very important point* to bear in mind, namely that when cleaning aluminium-alloy pistons, the metal of which is comparatively soft, great care should be taken to avoid removing any of the metal—especially on the cylindrical surface and piston-ring grooves—otherwise there may be a loss of compression due to leakage of gases past the piston when it is reassembled in the engine.

A useful set of tools and brushes for use with small portable electric motors, in connection with the cleaning of pistons, cylinder heads, valve ports, and valve guides, is shown in Fig. 103. With the aid of the appropriate brushes, practically any type of engine can be decarbonised and bright-cleaned over the surfaces in question. The tools are made by Black & Decker, Ltd.

Another useful garage tool is the Wolf portable electric motor and its cleaning wire brushes and stones. The use of the tool, with an end-type wire brush for cleaning the cylinder head of an engine, is illustrated in Fig. 104, whilst the method of using the machine, with suitable shapes of grinder for the valve passages and manifolds, is shown in Fig. 105.

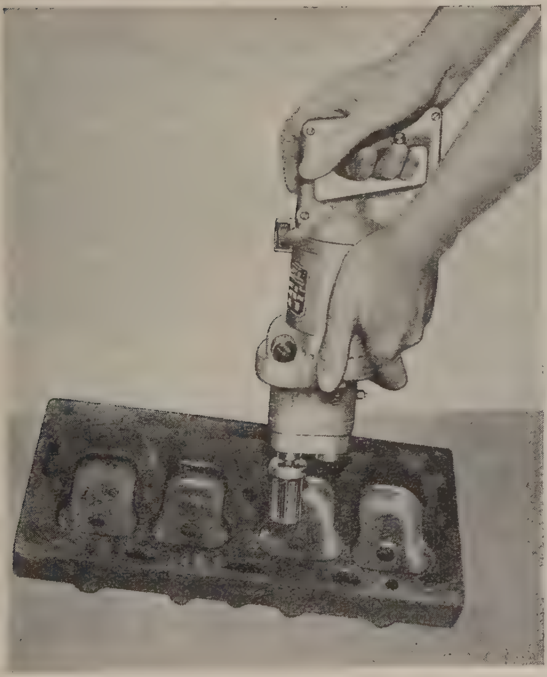

Fig. 104.—The Wolf Portable Electric Tool, with Wire-brush Attachment.

Cleaning the Valve Ports and Guides

Apart from the combustion chamber, carbon is liable to form on the cylinder metal surrounding the valve seatings underneath the valve heads (Fig. 106). This is confined to the exhaust-valve ports, hardly any carbon deposit being found in the inlet ports. The reason for this is that the burnt oil and carbon from the richer mixtures is swept out of the exhaust port and, on account of the very high temperatures, some of the carbon becomes deposited on the metal of the valve ports. This carbon is usually very hard, and may be difficult to remove. Unless it is cleaned off, the valve-port area may be reduced; further, the presence of a layer of non-conducting carbon will result in higher exhaust-valve and port temperatures, leading to a loss of power.

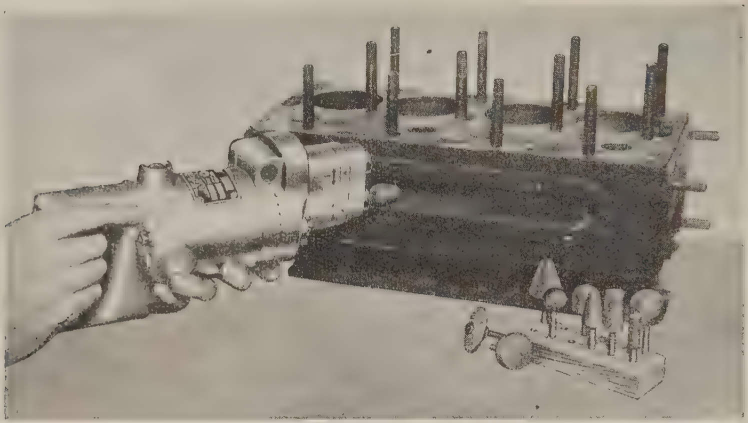
Fig. 105.—Using the Wolf Electric Tool with Grinding Attachment for cleaning Valve Ports.

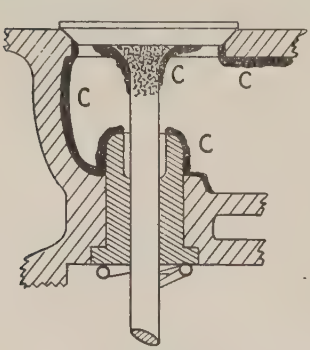

Fig. 106.—Showing, in Black, Places of Carbon Deposit (C) on Valve and Valve Port.

The hard carbon must be removed with rotating wire brushes of suitable form; chipping or scraping with metal tools is not usually very effective. When decarbonising valve ports, care must be exercised to avoid damaging the valve seatings, although any slight scratches will normally be removed when the valves and seatings are subsequently reconditioned.

The hole in the valve guide sometimes becomes coated with partly burnt lubricating oil. It is usual, therefore, to remove this deposit with a flexible spiral wire brush, of barrel shape, as shown in Fig. 107. The brush is rotated by means of a portable electric drill and, whilst rotating, is moved up and down the valve-guide hole until the metal is quite clean. These valve-guide cleaners are made in various sizes to cover the range of engines having from $\frac{1}{4}$–$\frac{5}{8}$-in. valve-guide holes.

Cleaning the Piston-ring Grooves, etc.

Once the piston has been stripped of its gudgeon pin and rings, the next step is to get rid of the carbon deposits (due chiefly to the burnt oil) which invariably form not only on the crown or piston head but also behind the piston rings in the piston grooves, and finally inside the piston underneath the crown. The piston is subjected to the full effects of the explosion temperature, and in consequence the crown gets very hot, whilst the part below experiences a lower temperature, being farthest away from the source of heat; moreover, it is, to a big extent, cooled by the lubricating oil on the cylinder walls. There is, therefore, the greatest amount of carbon to be found on the piston head, and if the piston runs fairly hot there will also be a deposit of carbon from the oil splashed up inside the piston; the greatest amount will be found under the crown.

The cylinder lubricating oil is also carbonised behind the piston rings, in the piston slots, the greatest amount occurring behind the top ring, and in diminishing amounts, as a rule, as one approaches the piston skirt.

This carbon deposit is often so plentiful that the rings become packed solid from behind; this is a common failing with two-stroke engines.

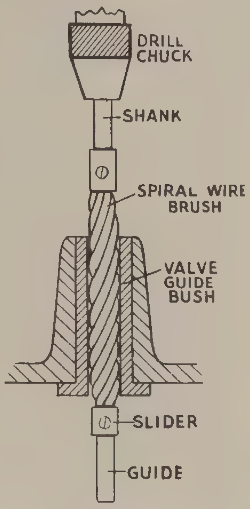

Fig. 107.—Cleaning the Valve Stem Guide.

To remove the carbon from behind the rings in the piston grooves a screw-driver can be used, but it is better to make a special tool out of an old square file or piece of flat strip. The scraping end of the tool should be slightly less than the width of the piston-ring groove, and a chisel or oblique edge should be left for scraping purposes. It will be found advantageous to turn the scraping edge perpendicularly to the

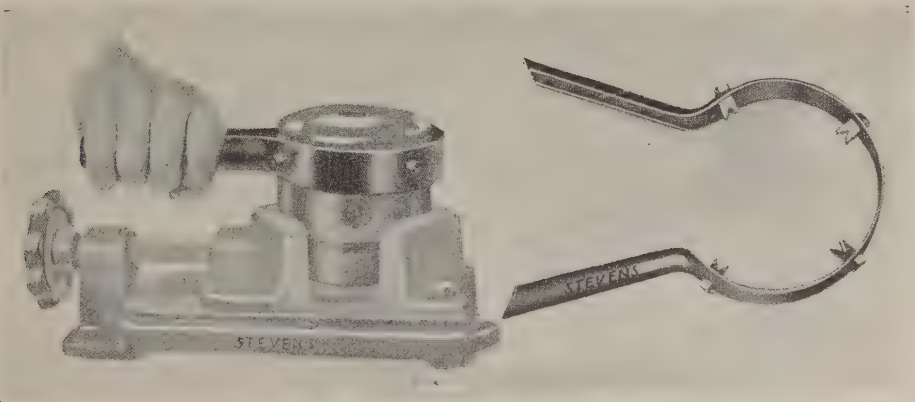

Fig. 108.—Piston-groove Cleaning Device.

length of this tool. Care should be exercised in scraping out the carbon not to scrape the metal of the grooves, or gas leakage will occur.

Many modern garages which in the course of their work have to deal with a fairly large number of engine overhauls often employ special piston-groove cleaning tools similar to the Stevens tool (Fig. 108).

In this illustration the piston is shown (on the left) held in the piston vice previously described, and the ring-groove cleaning tool is shown in operation. The illustration on the right shows the design of the tool in question. It consists of a spring steel ring provided with curved-section handles or grips, and having four projecting scraping points spaced at approximately equal intervals. The spring ring is compressed around the piston, with the points in the groove, and the tool is rotated around the piston for about one-quarter of a turn with the pressure maintained. At the same time, as the scraping points are not so wide as the piston groove (depth), the tool is raised up and down as it is rotated. This action completely cleans both the side walls and the bottom of each ring groove.

Fig. 109 illustrates the Churchill VLC piston-groove cleaner which greatly facilitates the removal of carbon and burnt oil from piston-ring grooves. To operate this tool, unscrew the handle and revolve the cleaning disc until a scraper of the correct width comes over the V-shaped flange. Then tighten the handle and place the piston on the flange. Next, lower the scraper into the groove and rotate the piston, at the same time applying pressure with the handle. Continue the rotation until the groove is quite free of deposit.

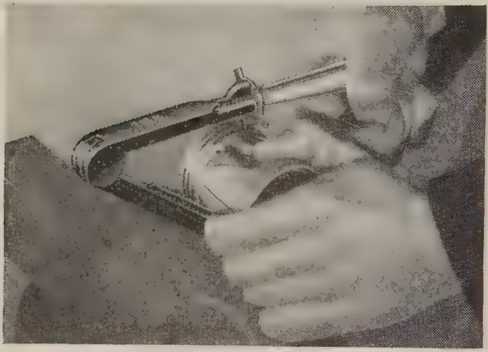
Fig. 109.—The Churchill Piston-groove Tool.

Oxygen Decarbonising Method

A method of decarbonising that was popular in the days of the non-detachable head type, or solid cylinder block, utilised a nozzle conveying pure oxygen under a low pressure to burn away the carbon in the combustion chamber. A small cylinder of oxygen at high storage pressure was employed in conjunction with a low-pressure reducing valve, flexible tubing, and nozzle. After warming up the engine and then running the hot water out of the cooling system, the oxygen nozzle was inserted through the sparking plug, or valve cap hole, and the carbon ignited by means of a lighted wax taper. The carbon was thus burned off, and when all combustion had ceased and the flame died out, the oxygen jet was turned on a little more in order to blow all carbon dust away. This was a quick and effective method of decarbonising an engine.

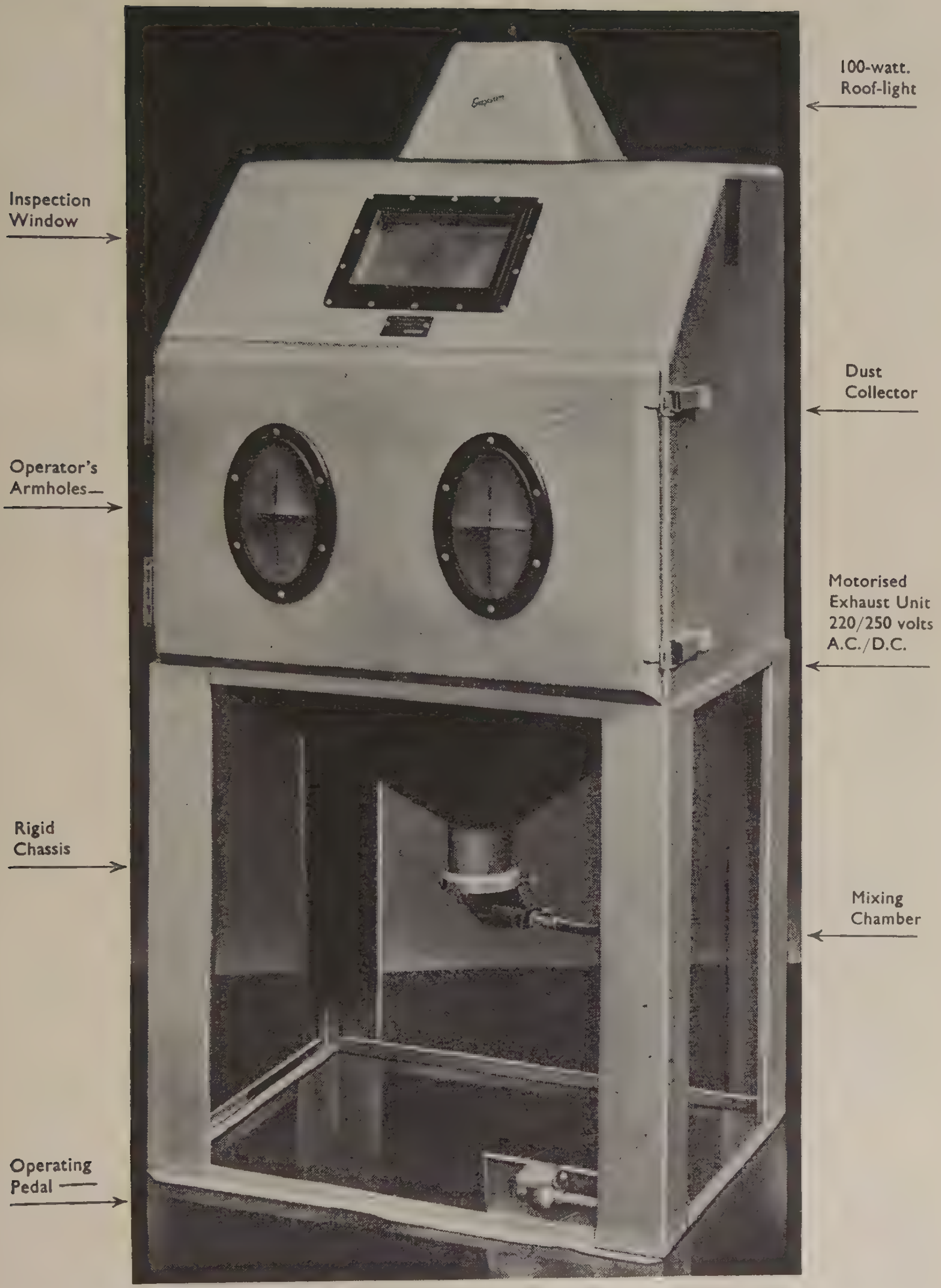

Fig. 110.—The Guyson Shot-blast Cabinet for Decarbonising Cylinder Heads, etc.

The Shot-blasting Method

A modern method of decarbonising cylinder heads and blocks is to employ shot-blasting, in which abrasive particles are projected in a compressed-air stream against the carbonised surface. The abrasive medium employed consists of steel particles, known as Medium (40) Steel Abrasive, which are projected at 120 lb. per sq. in. pressure on to the surface to be decarbonised. The abrasive penetrates into all cavities, e.g. sparking-plug holes and under the valve seatings, manifolds, etc., and thoroughly cleans the surface. A typical shot-blast cabinet is the Guyson[1] one shown in Fig. 110. This has two holes for the operator's hands and an inspection window to the cabinet in which the component is placed for decarbonising. The operator guides the shot-blast nozzle, which has a flexible tubing to connect up with the compressed air and shot supplies. The operator wears rubber gloves. A foot pedal is provided for controlling the blast gun.

Water-jacket holes in the cylinder head should be plugged with cotton waste or a blank cover. As the shot blast will not act on a greasy surface, the surfaces should be free from oil or grease.

The average time required to decarbonise the Ford V-8 cylinder head is only 3 minutes, and here it should be mentioned that the shot does not injure the bare metal or machined metal surfaces of the cylinder heads or pistons. The same method is used for cleaning dirty sparking plugs.

Scrapers for Decarbonising Purposes

Where wire-brush tools are not available, suitable shapes of scrapers can be employed to remove the carbon. The ordinary flat scraper is useful for piston crowns and valve heads, and the curved-edge and bent-end scrapers for radiused parts of the combustion chamber and valve pockets.

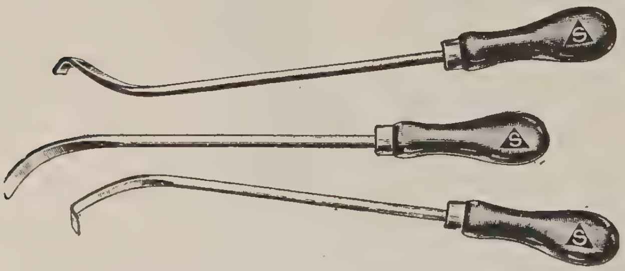

Fig. 111.—A Set of Carbon-removal Tools.

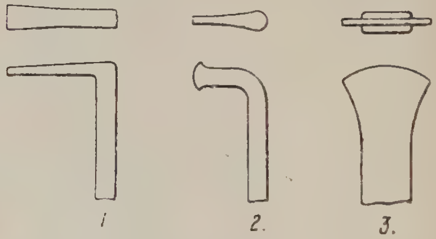

Fig. 112.—Some Useful Home-made Carbon-removal Tools.

The mechanic can readily make a set of scrapers out of worn files, ground down and shaped as shown in Fig. 112. When the metal has been softened, as after bending the end of the tool, it should be quenched from a cherry-red heat and then let down to a light straw colour, to give the maximum hardness and toughness. Referring to Fig. 112, Nos. 1 and 2 are suitable for scraping carbon from corners and under valve seatings, i.e. the valve ports. No. 3 is useful for flat or slightly curved surfaces. The flat scraper (not shown) should also form part of the carbon scraping tool set.

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[1] Guyson, Ltd., Leeds, 5.

Fig. 111 illustrates a proprietary make of tools for both blind-end cylinders and those with detachable heads.

Cleaning the Cylinder

After the cylinders, pistons, and valves have been decarbonised they should be cleaned thoroughly of all particles of solid matter, first by means of a compressed-air blast—a tyre pump is a good makeshift—and then with a cloth soaked in paraffin or petrol. Finally, give a good rub round with a clean soft cloth, and then cover all cylinder openings with cloths until ready for replacement on the engine.

Typical Examples of Engine Decarbonising

In order to illustrate in some detail the procedure adopted for decarbonising a modern motor-car engine we shall take as a typical example the engine shown in Fig. 113. This particular model is fitted with overhead valves operated by push rods and rocker arms. The procedure for decarbonising is as follows:

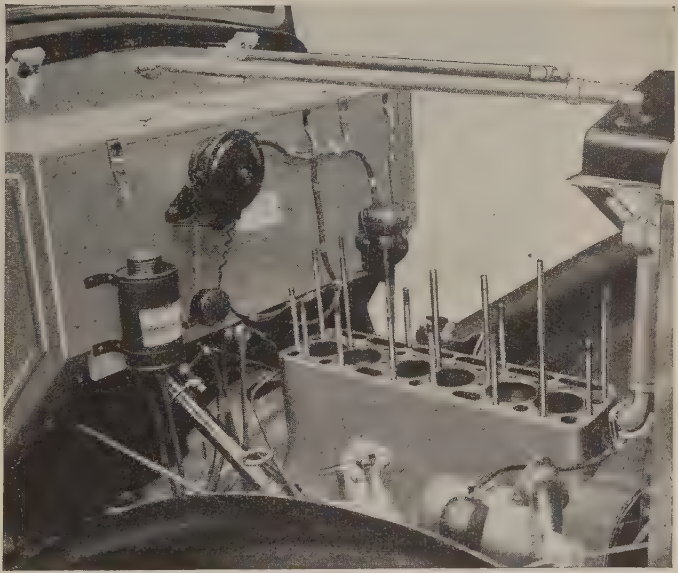


Fig. 113.—Typical Car Engine, showing Cylinder Head removed for Decarbonising.

Remove the bonnet complete. Drain all the water from the radiator and cylinders. Remove the petrol pipe, throttle control, and the oil pipe leading to the valve-rocker shaft. Remove the high-tension leads from the sparking plugs and dismantle the exhaust pipe from its manifold. Undo the top water pipe from the cylinder head. Remove the air silencer from the carburettor and valve cover, and remove the valve cover. Undo the nuts holding the rocker shaft. These should be undone steadily, a few turns each one at a time. This is necessary, as some of the valve springs will be under compression and the valves open. Remove the rocker shaft complete. Remove the push rods and mark them so as to be sure that each one is returned to the same position as it was before dismantling. If it is desired to remove the valves and grind them in, it is advisable to remove the valve springs at this stage. Undo the cylinder holding-down nuts. Lift the cylinder head, complete with carburettor pipes, away from the block. After removing the cylinder head and its gasket, turn the engine round by hand and scrape off the carbon from the top of each piston as it reaches the top of its stroke, carefully cleaning all particles of carbon away as the top of each piston is cleaned. Also remove all carbon from the cylinder-head combustion chambers. Replace the head by reversing the foregoing operation order. Use a little jointing medium on each side of the gasket, a new gasket being used should the old one be damaged in any way. If it is necessary to grind in the valves this should be done when the cylinder head is removed, the valves being ground in in the usual way. It is important that each valve is checked for correct seating after regrinding. To do this thoroughly, clean the grinding compound from the valve and valve seat in the cylinder head. In order to test the seat, thoroughly dry the valve, *smoke the seat over a candle flame* or oil flame with an even coating of soot, insert the valve in position; holding it lightly on its seat, rotate it to and fro about $\frac{1}{8}$ in., remove for inspection, and if the seating is thoroughly ground in the soot will be fairly evenly distributed over the whole circumference of the valve seat. After grinding in the valves the valve clearances should be set.

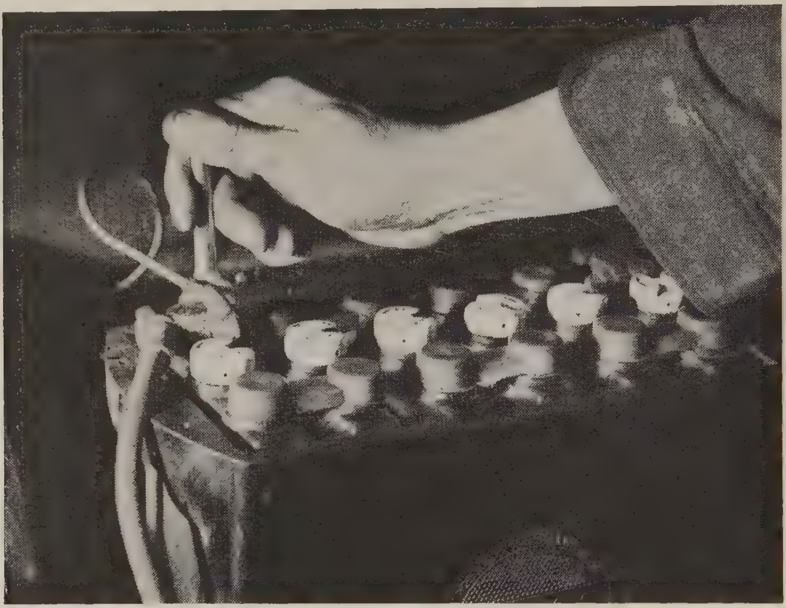


Fig. 114.—Before Decarbonising disconnect One of the Battery Cables from its Terminal as a Safety Measure.

The detailed procedure involved in decarbonising the post-war Austin 10-h.p. four-cylinder engine is as follows:

The first job is to drain off the cooling system by opening the drain tap at the bottom of the radiator. Take care to preserve any anti-freeze mixture by placing a receptacle with a capacity of at least 20 pints under the radiator before opening the drain tap.

While the water is draining, place protective coverings over the front wings to prevent damage to the cellulose, and disconnect one of the battery leads to guard against the inadvertent operation of the starter (Fig. 114).

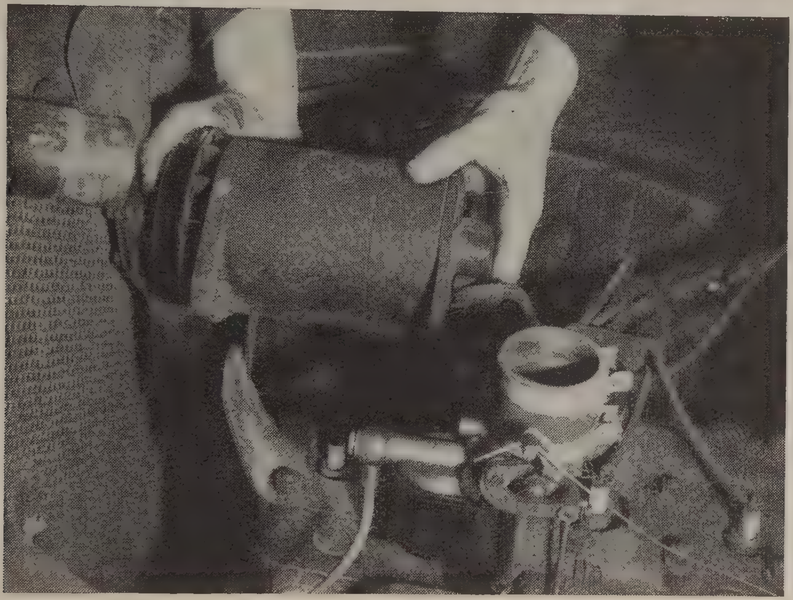


Fig. 115.—The Dynamo is lifted from its Mounting and laid alongside the Steering Column, after its Three Securing Bolts have been removed. The Dynamo Cables need not be disconnected.

The two bonnet sides should next be removed by disconnecting the two bolts joining each to the cowl and body. Note that the near-side front bolt for the bonnet side must be replaced to fix the bonnet stay rod in position. A useful tip to bear in mind when partially dismantling any mechanical component is to replace all nuts and bolts on their components, or, if this is not practicable, to store them in a container of some sort. This plan saves much time and temper when reassembling.

The cooling-system top water hose and the air cleaner hose are easily removed after their securing clips have been loosened. The next component to be detached is the dynamo. First slacken the locking nut on the dynamo adjusting link, lower the dynamo and lift the fan belt over the dynamo pulley and fan. The dynamo may now be removed from the cylinder head and laid alongside the steering column after its two securing bolts have been detached (Fig. 115).

Disconnect the sparking-plug leads, and if the brass terminal at the plug end of each lead is not stamped with its correct cylinder number, mark each lead, noting that the front cylinder is No. 1. If this is done, replacing the plug leads correctly will be simplified.

Next remove the sparking plugs and all the cylinder-head holding-down nuts, releasing each a little at a time. This precaution prevents cylinder-head distortion.

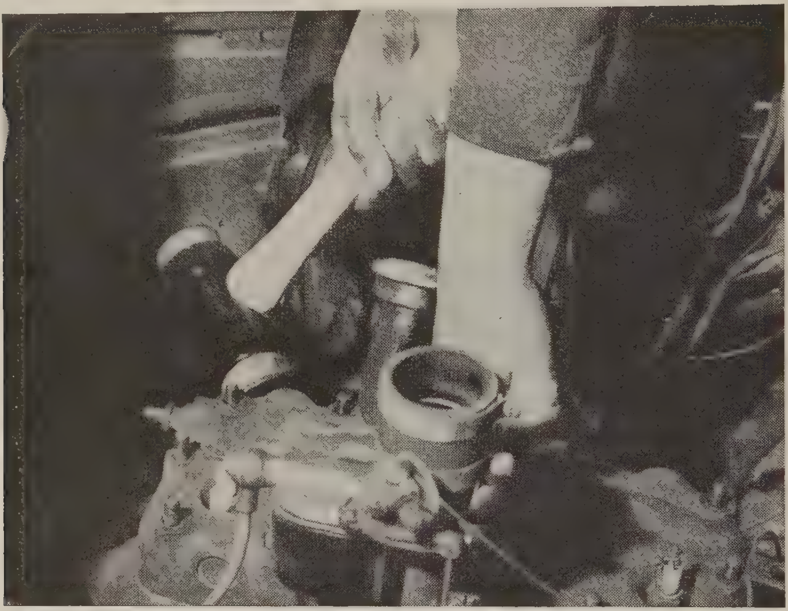


Fig. 116.—If the Cylinder-head Joint is difficult to break, a few taps with a Mallet or Rawhide Hammer will free it.

Sometimes it will be found that a cylinder-head stud comes away with its nut. When this happens the stud and nut should be separated by the use of two nuts threaded on to the other end of the stud and so locked together that they grip the stud firmly, so that it can be held without damage to the thread. The freed stud may afterwards be replaced in the block after the thread portion of the stud entering the block has been dipped in jointing compound.

When all the cylinder-head nuts have been removed the head may be lifted. If difficulty is experienced a few light taps with a mallet against the side of the head should be sufficient to break the joint (Fig. 116). Never, in any circumstances, wedge a hard object between the head and the block in an attempt to lever the head free. Such a practice may easily lead to a local fracture of the cylinder head or engine block, and inevitably damages the gasket.

The gasket should next be carefully lifted over the studs. Whereas the usual practice is to renew the gasket each time the engine is decarbonised to ensure a really good joint when reassembling, if the valves are to be ground in at a later date renewal of the gasket is best left till then, provided that the old gasket is not damaged on removal.

The carbon deposit now exposed on the cylinder head and piston crowns should be of a hard and dry appearance. If there is any tendency towards an oily deposit, then either the cylinders are worn or certain piston rings are sticking. If the deposit has a soft, rather fluffy appearance an over-rich carburettor mixture is indicated. The first fault will call for consideration, in relation to oil-consumption experience, as to whether a cylinder rebore and new pistons are desirable. For an over-rich carburettor mixture attention should be given to the choke control, slow-running adjustment, and float-chamber assembly.

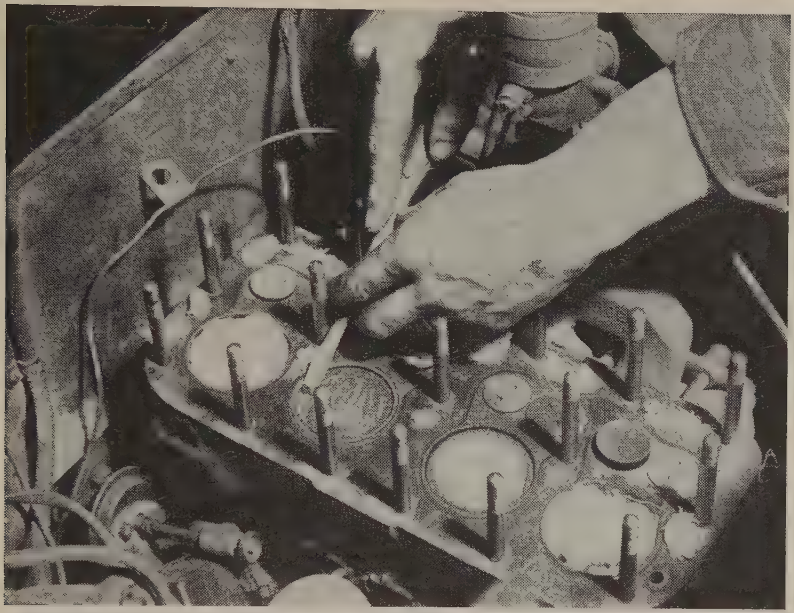


Fig. 117.—An Old Piston Ring provides a Useful Guide for preserving the Carbon-ring Oil Seal on Piston Crown.

Removing the carbon from the cylinder head is a job which may be easily performed on the bench (Fig. 118). Use a blunt scraper, such as a screw-driver or an old file ground to a wedge shape at the end, but be careful not to bend too closely over the head when removing the carbon, as this has a nasty habit of flying out in all directions and is very painful if it enters the eye.

Before removing carbon from the engine use the starting handle and carefully examine the valve seats as each valve is fully opened. Seats which have small black pin-prick holes on their surface, i.e. are pitted, will need the attention of an expert with a valve-cutting tool, but those seats which present a smooth appearance with occasional dark markings formed by carbon deposit may be restored by the normal grinding-in process. Seats which appear uniformly clear and well defined may be left until a later period, although this procedure is not one to be recommended normally if the best possible engine performance is desired.

The next job is to remove the carbon from the piston crowns and from the top of the engine block. Turn the engine until number one piston is at top dead centre and then place clean rag in the adjacent open cylinder and water ports to prevent the ingress of carbon particles.

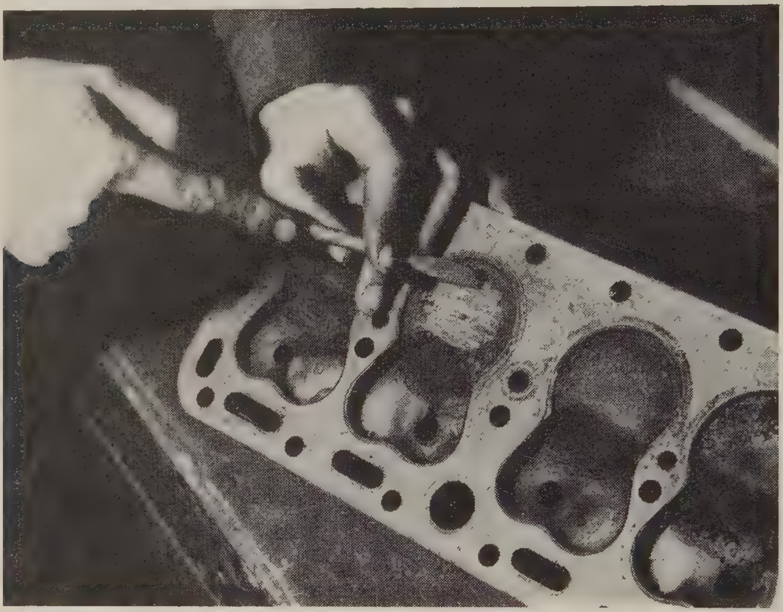


Fig. 118.—Scraping away Carbon Deposit from the Cylinder Head.

It is advantageous, as briefly mentioned earlier, for a thin ring of carbon to be left on the periphery of the piston to ensure that a good oil seal is preserved between the piston and the cylinder (Fig. 117). An old piston ring is useful for this. With the piston just off top dead centre, the old ring may be pressed into the cylinder bore and then when all carbon within the area defined by the ring has been removed, it will be found that a useful oil-sealing carbon ring has been left on the piston. Take care not to press heavily on the scraper tool when removing carbon from the aluminium-alloy piston crown or undesirable scoring of the metal will result.

When removing carbon from the valve area, make sure that both valves are closed, since this obviates the risk of the scraper slipping and scratching the valve seating.

This procedure outlined for removing carbon from number one cylinder should now be repeated for number four and then numbers two and three cylinders.

After all carbon has been removed smear a little clean grease or lubricating oil on the cylinder walls and turn the engine slowly by hand. By removing any oil or grease left at the tops of the cylinders by the descending pistons any carbon that has found its way into the cylinders will be trapped and removed with the oil or grease. The traces still left on the cylinder walls will, of course, assist in initial lubrication of the cylinders when the engine is restarted.

Before replacing the cylinder-head gasket clean off all dirt from the face of the engine block and from both sides of the gasket. Then lightly smear both sides of the gasket with stiff grease or jointing compound (not a cement) and replace with the beaded edge downwards. Clean up the face of the cylinder head and lower into position over the cylinder-head studs.

Tightening Cylinder-head Nuts

An important point arises in connection with the tightening of the cylinder-head nuts. These must be tightened each a little at a time, commencing from the centre and working outwards, and it is always advisable to check them again after the engine has thoroughly warmed from its first run. At the same time examine the cooling-system hose connections to make sure that they are not leaking.

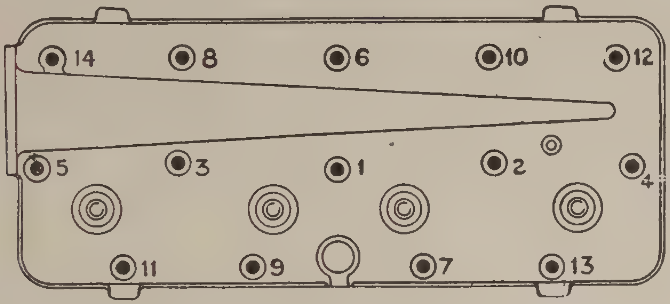


Fig. 119.—Showing order of tightening Typical Cylinder-head Nuts.

Fig. 119 illustrates a typical car engine cylinder head, and shows the order in which the nuts should be tightened, namely commencing with No. 1 and proceeding with the others in numerical order. In this case the central line of nuts is first tightened and then the outside lines of nuts in alternating order. Many manufacturers prefer the spiral order of tightening the cylinder-head nuts, however. A good example of this method is that of the Leyland engine cylinder head shown in Fig. 120.

Tightening Nuts on Aluminium Heads

It is most important to tighten the nuts on aluminium cylinder heads *only when the heads are cold.* After the engine has been in service for a few hundred miles following reconditioning or after it is new, do not tighten down the nuts with the engine hot, as is done with the nuts on cast-iron heads, but wait until the engine cools down, otherwise severe thermal stresses will be put on the holding-down studs and their nuts.

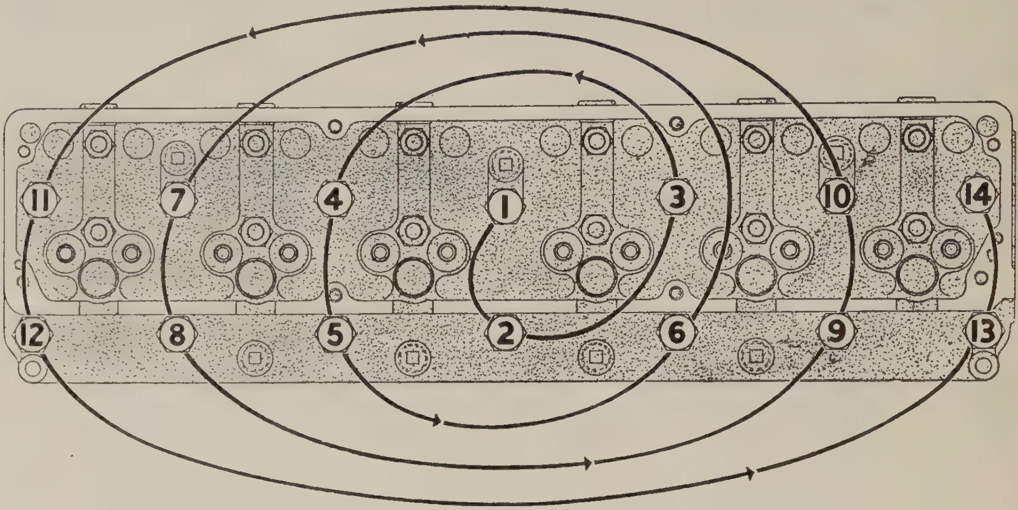


Fig. 120.—Order of tightening Leyland Oil-engine Cylinder-head Nuts.

When untightening cylinder head nuts, the reverse order to that of tightening up should be followed.

CHAPTER 6

REMOVAL AND REPLACEMENT OF PISTONS, RINGS, AND VALVES

Removal of the Pistons

It will here be assumed that the pistons are exposed, the cylinder head having been removed; also the oil sump.

The pistons must first be removed from the connecting rods either on the "job" itself or, where possible, after the rod assemblies have been removed to a convenient bench for dismantling.

In the absence of special tools for removing the gudgeon pins, it is first necessary to ascertain how the latter are fitted and what locking means are employed. In certain earlier designs one end of the gudgeon pin was tapered, and the pin was driven into the piston-pin bosses, which were suitably tapered. In addition, many pistons had locking devices, in the form of set-screws or tapered pins inside the piston through the bosses; these screws were usually locked by means of split-pins or a wire ring.

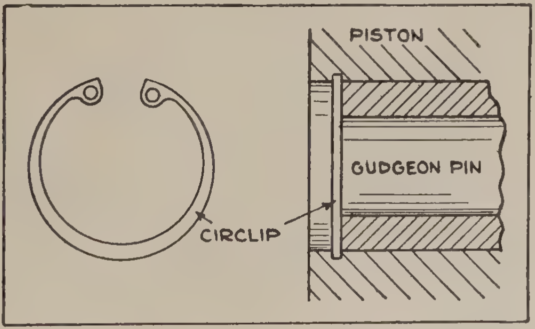


Fig. 121.—"Circlip" Method of holding Gudgeon Pin.

The "Circlip" spring-ring device is now one of the most popular; this is shown in Fig. 121.

Having removed the locking screws or devices, the services of an assistant, to hold one side of the piston, are usually desirable, otherwise the connecting rod may be bent in the operation of driving out the gudgeon pin. The procedure is for the assistant to hold the piston firmly on the opposite side to which the operator drives out the gudgeon pin with a hammer and brass or copper drift; a hard blow is better than a series of gentle taps in starting the gudgeon pin.

If the piston-connecting-rod assembly can be taken to a bench it is a much easier operation to remove the gudgeon pin, for the piston can be placed in a hollow or semi-cylindrical wooden block, having a suitable size of hole for the gudgeon pin to be driven into. Fig. 122 illustrates a convenient form of gudgeon-pin removal block and its method of use.

On no account should the piston be laid on a metal table or vice for the purpose of driving out the gudgeon pin, or even on a metal V-block, as there is a risk of cracking or distorting the metal of the piston. The piston skirt is usually very thin and easily damaged by careless handling or knocking; aluminium-alloy pistons are also easily damaged. It is sometimes advisable to remove the piston rings before hammering out the gudgeon pin, even when the piston and rod are not removed from the crankcase unit; there is always the possibility of a misdirected hammer blow striking one of the piston rings, so that their removal before the gudgeon pin is advisable.

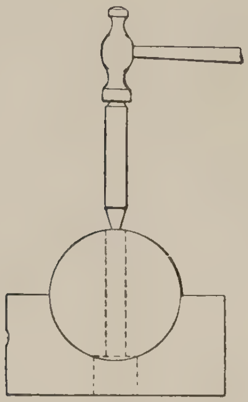


Fig. 122.—Removing the Gudgeon Pin.

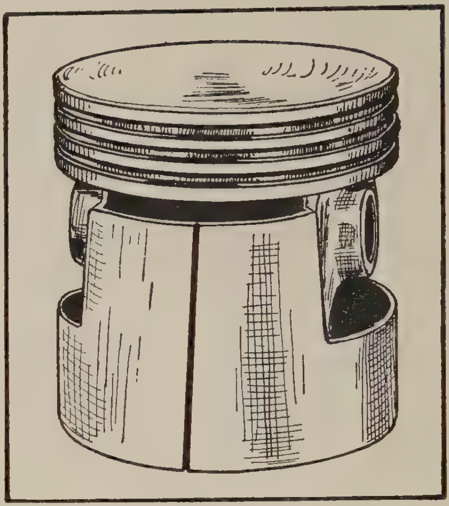


Fig. 123.—Typical Split-skirt Aluminium-alloy Piston.

The methods outlined are more suited to the home workshop or garage and in similar cases where the worker has not the proper equipment for dealing with this job. It is usual, in the case of repair garages and engineering shops, to employ special tools or devices for quickly removing gudgeon pins without the necessity of hammering them out.

Thermal Fit Method

In some engines the gudgeon pins are a light-press fit in the piston bosses and a bearing fit in the connecting-rod small-end bushes.

One method of inserting the gudgeon pin, adopted by a large motor manufacturing concern, is to employ a piston jig, surrounding all of the piston with the exception of the gudgeon-pin holes. The jig is provided with an electric resistance heating coil, and this raises the temperature of the aluminium-alloy piston sufficiently to expand, or enlarge, the gudgeon-pin holes. As soon as the required temperature for this is attained, the cold gudgeon pin is quickly pushed through the front gudgeon-pin hole, the small-end connecting-rod bush, and the rear gudgeon-pin hole.

The piston is then removed from the jig and allowed to cool, when the gudgeon pin is found to be held firmly in the piston bosses. The gudgeon pin can be removed in a similar manner, but it is sometimes necessary to run cold water through the hollow pin when the piston is heating up.

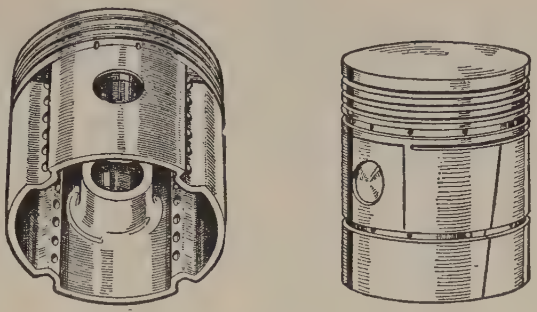


Fig. 124.—Two other Designs of Light Aluminium-alloy Pistons.

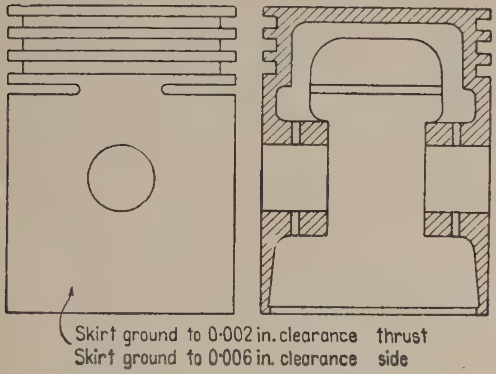

Skirt ground to 0·002 in. clearance thrust
Skirt ground to 0·006 in. clearance side

Fig. 125.—The Oval-section Aluminium Piston which is used to prevent Piston Slap. The Dimensions of the Skirt Diameters are given above.

It may be added that, with many designs of aluminium pistons, if the head of the piston is immersed in boiling water up to just above the level of the gudgeon-pin bosses and left for a few minutes, the piston-pin hole will expand enough to permit the gudgeon pin to be tapped lightly into position.

Gudgeon-pin Removal Devices

There are a number of devices on the commercial market for removing gudgeon pins from pistons; these are sold by the motor accessory dealers and larger garages.

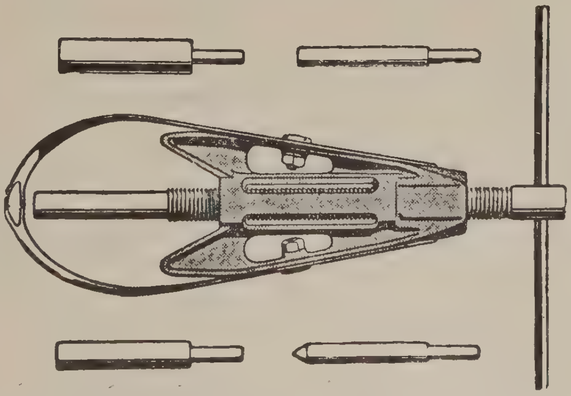


Fig. 126.—The "Millennium" Gudgeon-pin Extractor.

Fig. 126 shows the "Millennium" gudgeon-pin remover supplied by Messrs. Brown Bros., Ltd., London. It consists of a strong steel strap for encircling the piston, and a screw-operated extractor plunger, provided with a convenient screwing handle or tee. The strap has a suitable size of perforation arranged opposite the plunger, to allow the gudgeon pin to pass through during extraction. To use this device, the screw is turned until the piston can be inserted in the opening enclosed by the strap and the plunger or V-piece forming the nut, when the screw is rotated with the plunger opposite the gudgeon pin until the latter is forced through the hole in the strap. This device, which is provided with the plungers shown made from hardened steel and in various sizes, does not damage the piston in any way, and will usually remove the tightest gudgeon pins.

A makeshift device, which, however, is very effective, can be employed in the case of pistons fitted with hollow gudgeon pins, in the absence of a proper gudgeon-pin extractor. It is only necessary to have a bolt with its head, A (Fig. 127), turned down to a little under the size of the gudgeon pin's outer diameter, and a piece of hard wood or brass tubing, C, having an internal diameter a little larger than that of the gudgeon pin's outer diameter. The tube should have a length of about one-half that of the gudgeon pin. The method of using this device will be apparent from the sketch. The nut B is screwed up progressively, thus causing the screw head A to force the gudgeon pin towards the left in the hollow tube.

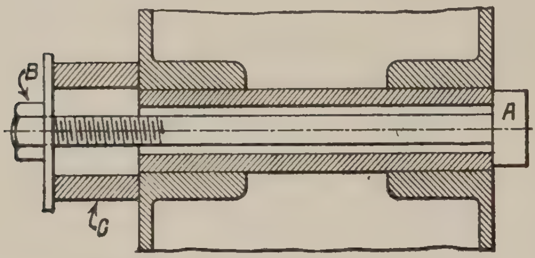


Fig. 127.—A Gudgeon-pin Extractor.

Removing Split-end Connecting-rod Pistons

In certain designs of engine the gudgeon pin is clamped to the small end of the connecting rod by means of a split end to the latter and a pinch screw; the Wolseley, Morris, and Austin engines use this method. To remove the piston the big-end cap of the connecting rod is first taken off from the sump side and the connecting rod with its piston withdrawn from the latter side of the cylinder. The piston is then clamped in a vice using a pair of shouldered plugs at the ends of the gudgeon pin, as shown at A in Fig. 128. The pinch screw, after removing the locking device, e.g. split pin, is then unscrewed with a box spanner, and the gudgeon pin tapped out of the piston.

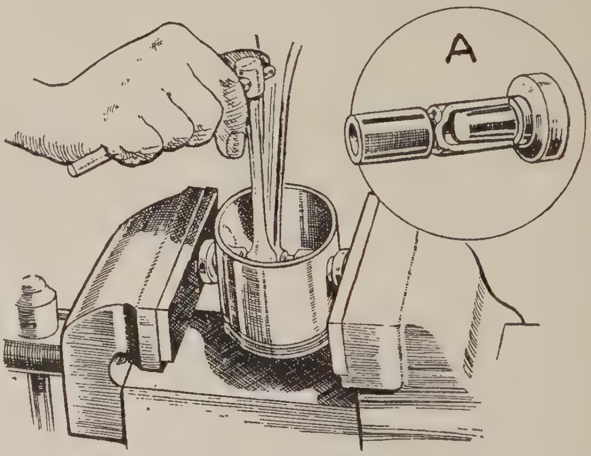


Fig. 128.—Removing Split-end Connecting-rod Pistons.

Removing the Austin Piston Assembly

Fig. 129 illustrates the piston, connecting rod, and shell-type bearings of the Austin 12-h.p. engine, which, it may be stated, is typical of other recent models. The piston is removed from the engine by first taking out the two split pins and unscrewing the nuts holding the big-end bearing together. The heads of the big-end bolts are anchored in the top half of the big-end by a small peg. When replacing, see that the pegs are in their correct positions. Now revolve the crankshaft by hand, and as sufficient room becomes available between the crankcase and crankshaft withdraw the piston and connecting rod, being careful not to damage the piston or its rings. A piston-ring guide should be used when replacing the piston.

The gudgeon pin is clamped to the small end by a pinchbolt, the latter being set at an angle and held by a spring washer; it screws into the upper boss of the small end of the connecting rod. The gudgeon pin is a rocking fit in the aluminium-alloy piston boss holes. The pinchbolt is removed with the aid of the long box spanner supplied in the engine servicing kit of tools.

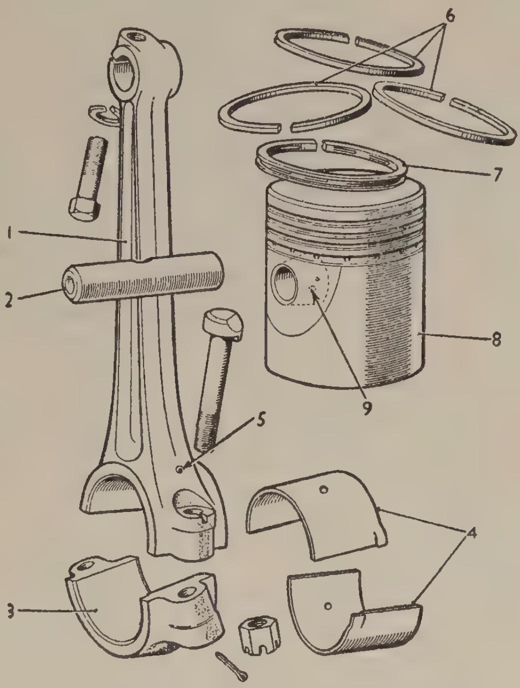


Fig. 129.—The 12-h.p. Austin Piston Assembly.
1, Connecting Rod. 2, Gudgeon Pin. 3, Big-end Cap. 4, Half Shell Bearings. 5, Oil Jet. 6, Piston Rings. 7, Bottom Oil Control Ring. 8, Piston. 9, Oil Hole.

Removing Piston Rings

Continuing our outline of engine-dismantling operations, and having either removed or exposed the pistons, the rings should next be carefully removed; without special care the cast-iron rings may easily be broken, as they are fairly brittle.

It is not absolutely necessary to be provided with special piston-ring removing appliances, for a skilled mechanic can usually remove the rings by hand only; it is advisable, however, to employ two or three thin strips of tinned iron or brass—in an emergency narrow hacksaw blades will do—and to insert these one at a time behind the ring to be removed. The best method is to press the portion of the ring opposite the piston-ring slot firmly into its groove so that the split side stands out beyond the piston. Next insert one of the metal strips behind the ring and work it round about one-quarter way. Then insert the second strip, and work both around to convenient positions to enable the third strip to be inserted. Finally space the strips around the piston equally. The piston ring will now be found sufficiently sprung open to slide it off along the strips.

As regards the spacing of the strips, perhaps the best positions are when two of these are set at about one-half from the joint in the ring and the third blade set directly opposite the joint; in this way the rings can be removed without breaking. Each of the three rings (usually fitted) should be removed in this way.

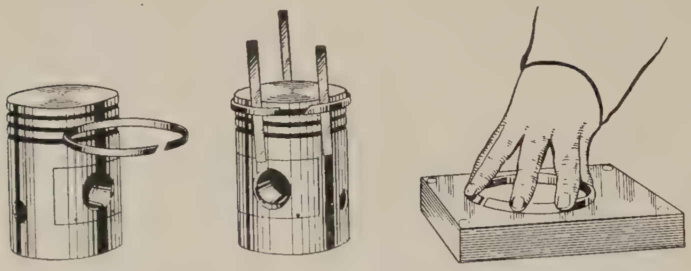
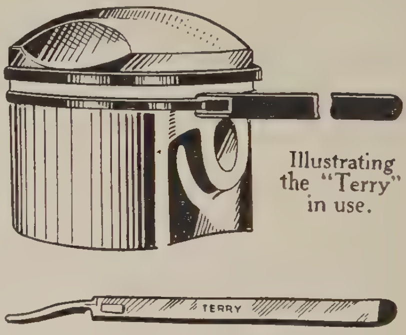


Fig. 130.—Illustrating Testing, Removal, and Grinding of Piston Rings.

The Brico piston-ring removal and replacement tool, illustrated in Fig. 295 on page 242, is a development of and improvement on the three-blade method of removing piston rings.

A thin knife-blade can also be used for removing the piston ring, or, better still, a specially thin stiletto tool can readily be made to do this job; it should be fitted into an ordinary tool handle. The knife-blade, or tool, should be slipped under one of the two ends of the piston ring, and gradually worked round, at the same time lifting the free end of the piston ring upwards with the fingers, as shown in Fig. 130; the ring will be found to come off quite readily, but no appreciable amount of force should be exerted.


Illustrating the "Terry" in use.
TERRY
Fig. 131.—The Terry Piston-ring Tool.

The Terry piston-ring tool, shown in Fig. 131, will be found particularly convenient for removing gummed or "free" piston rings. It consists of a steel shank having at its end a special prong for easing the ring (and also for removing the carbon in the piston-ring groove) and a slot for guiding the lifted portion of the ring during the easing operation. *It is advisable before using any piston-ring removal tool to give the piston-ring portion a good soaking in paraffin.*

Special piston-ring pliers are now made for the purpose of expanding the piston rings sufficiently to allow of their removal from the piston. The principle of most of these devices is that of a pair of special pliers having small projections which are inserted in the piston-ring slot, the two sides of the latter being forced apart by gripping the pliers; in some designs the pliers can be locked in any position; this facilitates piston-ring removal, for it leaves the hand free to manipulate the ring.

Fig. 132 illustrates the Wellworthy piston-ring tool, which is of the special spring-controlled pliers pattern in which the free ends of the ring are gripped and then moved away from each other. The ring is thus expanded correctly to the shape for just clearing the piston lands.

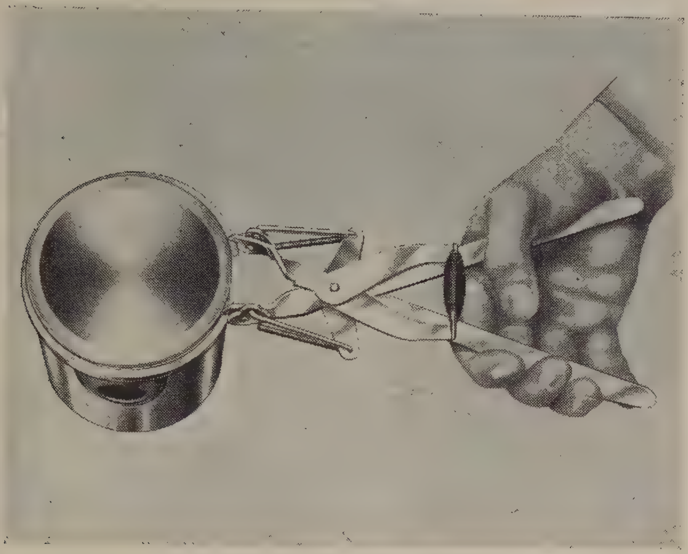


Fig. 132.—The Wellworthy Piston-ring Tool.

The Britool piston-ring expander, illustrated in Fig. 133, expands the ring by forcing the free ends apart, but at the same time preventing the ring from being distorted by excessive expansion when being removed or replaced. The method of using the tool, in the case of a Bedford piston, is illustrated in Fig. 133, from which it will be seen that the tool encircles the ring and expands it to the proper shape for removal.

The method of replacing the piston rings will be considered later.

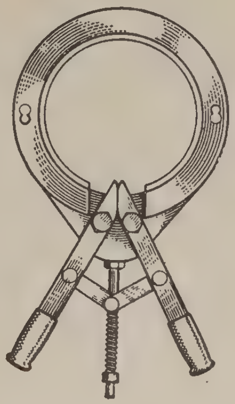


Fig. 133.—The Britool Piston-ring Tool.

Holding the Piston: Special Vices

The piston is an awkward object to hold firmly, on account of its shape and also its fragile nature—for the metal of the piston skirt is very thin, and whether made in cast iron or aluminium alloy is apt to be easily damaged if not handled properly.

It is, of course, highly undesirable to hold the piston in the ordinary engineer's vice, even with lead clamps, on account of the local stresses incurred. By employing a pair of semi-cylindrical blocks (as shown in Fig. 134), however, the piston can be firmly held without risk of damage. It is a simple matter to bore out a square block of wood—ordinary pine wood will do—in the lathe to about the diameter of the piston, and then to saw it in two across a diameter parallel to a pair of flat edges. If a thin metal strap, similar to that indicated in Fig. 134, be used for holding the two blocks together this will prevent the latter from falling apart when taken out of the vice. The ends (Fig. 134) are clamped in the vice; if a piece of tin be screwed to these faces the life of the device will be greatly prolonged.

Fig. 135 illustrates another form of vice jaws for holding pistons. This attachment is somewhat similar to the home-made device previously described, but is rather more convenient, as it embodies clamping plates to hold the two flexible wood blocks to the vice jaws. In smaller sizes this attachment can be used for holding bushes, gudgeon pins, and other cylindrical objects.

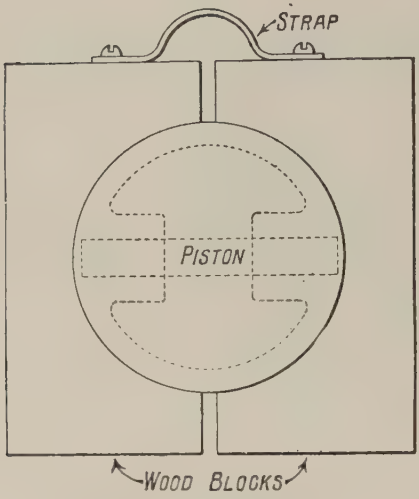


Fig. 134.—Piston-clamping Blocks.

The Stevens universal piston vice is illustrated in Fig. 136. It has been designed especially for the purpose of holding pistons of all sizes without injury, and for this reason is greatly to be preferred to the ordinary engineer's vice.

It has four points of contact on the surface of the two vertical angle brackets, and as the clamping faces of the latter are lead-lined the piston has actually four contact surfaces. One of the jaws (namely, that shown on the right, Fig. 136) is fixed, but it can be slid along and bolted down over a limited range of positions in order to accommodate different diameters of piston, as indicated by the dotted lines on the right in Fig. 136. The other jaw is moved by means of the hand wheel and screw shown on the left (Fig. 136), the base bracket or lug being threaded for this purpose.

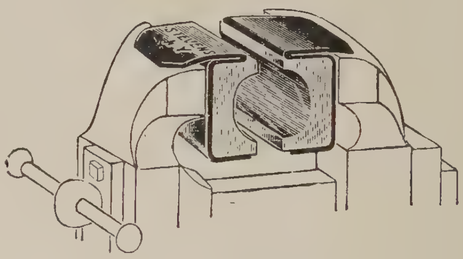


Fig. 135.—Piston-holding Vice Jaws.

The maximum diameter of piston accommodated by the piston vice illustrated is 5½ in.; the base measures 10½ in. × 5½ in. This vice can also be used for holding other automobile parts; for example, bearings, speedometer heads, ball bearings, and universal joints; it holds the work firmly, but not with an excessive pressure likely to injure the object held.

By fitting the two jaws with triangular-shaped metal or wooden blocks, this vice can be converted into the ordinary parallel-jaw type.

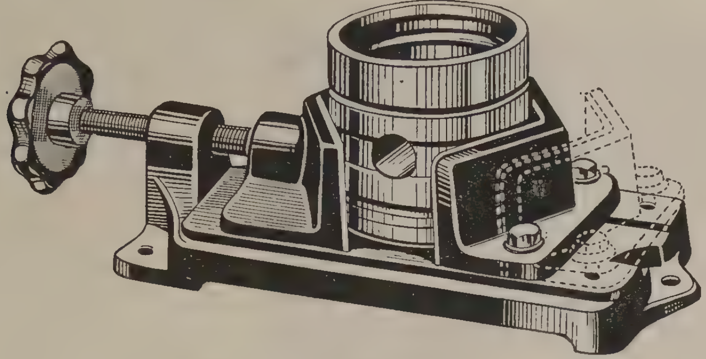


Fig. 136.—A Useful Piston Vice.

Removing the Valves

Having described the procedure for dismantling the cylinder blocks, detachable heads, connecting rods, crankshaft and piston components, we shall next consider the question of the removal of the valves, confining our remarks to the almost universally adopted poppet valves of the overhead and side-by-side type. Commencing with the former type, which, incidentally, is the easiest of any to remove, it is of course necessary in the case of detachable-head engines to remove first the cylinder head, when the valve heads are exposed. The cylinder head is placed on a suitable clean bench, with the valve heads underneath, and the valve springs are compressed with a screw-driver or other convenient tool—a slotted tube, to bridge the cotter pin, makes an excellent tool—and the cotter device removed. The pressure on the valve collar should then be released gradually, until the valve spring is fully extended and free from constraint, when it can be removed, together with its collar, by hand.

Many manufacturers supply special tools for compressing the valve springs in the case of overhead valves, for the purpose of removing the cotters, collars, and the springs themselves. The valves, as we have previously stated, are removed after the cylinder head has been detached, but a spring can usually be changed on the complete engine without dismantling the cylinder head, by making use of the sparking-plug orifice.

Valve Lifters

In the case of side-by-side valves, there is usually much more difficulty in connection with their removal, due to the fact that the valve springs and stems are often placed in "pockets" or recessed chambers in the cylinder castings, and are not very accessible, as a rule.

Specially designed tools have been on the motor market for some years for the purpose of facilitating the removal of awkwardly placed side valves. Whilst many are quite satisfactory for his purpose, some are not suitable for the operation. In the selection of a valve-lifting tool, if the makers do not supply their own type some consideration must be given to the actual design of the cylinders themselves, to the available space in the valve-stem chamber, to the presence of nuts, studs, and similar projections, and to the outside space available for manipulating the device. Many valve lifters will work quite well in the case of certain designs of cylinder, but will not in other cases, despite the so-called " universal " adjustments provided.

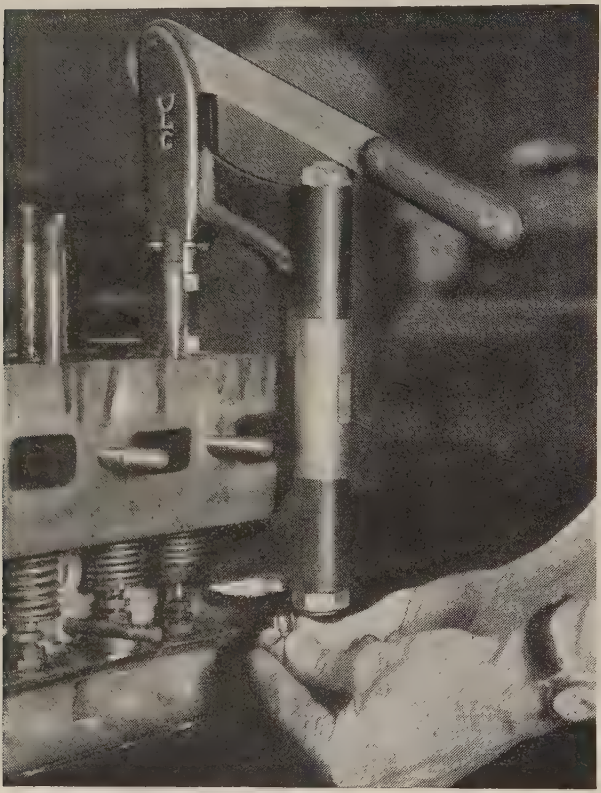


Fig. 137.—The Churchill Valve-spring Compressing Tool.

To the owner-driver or chauffeur we would suggest the use of the valve-lifting device recommended or supplied by the maker of his car; this will give the best results. To those who have to deal with all types of engine, two or three alternative types of the " universally adjustable " pattern should be obtained.

Regarding the available types of valve lifter, these are of two principal kinds, namely, those which merely lift the valve spring and collar to enable the cotter to be withdrawn, and have to be " hand-compressed " during the operation, and those which keep, or lock, the compressed valve spring in its position, thus leaving both hands free to extract the cotter or valve-collar locking device. The latter, although more expensive, are the better for all-round purposes.

The Churchill valve-spring compressor and cotter-loosening tool illustrated in Fig. 137 is designed for side-valve engines to exert a powerful vice-like grip that will loosen the most obstinate cotter. The special cam used is contoured to give a progressive movement, allowing a roller-ended plunger to move gradually at first to free the cotter; it then increases in speed until the valve spring is fully compressed. It is provided with interchangeable distance pieces, and is particularly suited to Hillman and Humber engines. An easily adjustable non-slip pad is fitted to the plunger and can be locked in position. A similar tool with straight foot is suitable for most standard car engines; there is a special variation of the tool for 8-h.p. and 10-h.p. Ford engines.

Fig. 138 illustrates the simple screw-clamp design of tool used for Austin 8-h.p. and 10-h.p. side-valve engines. The thumb-screw member holds the valve head down on to its seating, and when screwed causes the lower fork-end part to compress the valve spring farther.

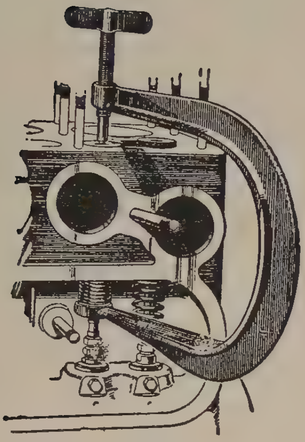


Fig. 138.—Austin Side-valve-spring Tool.

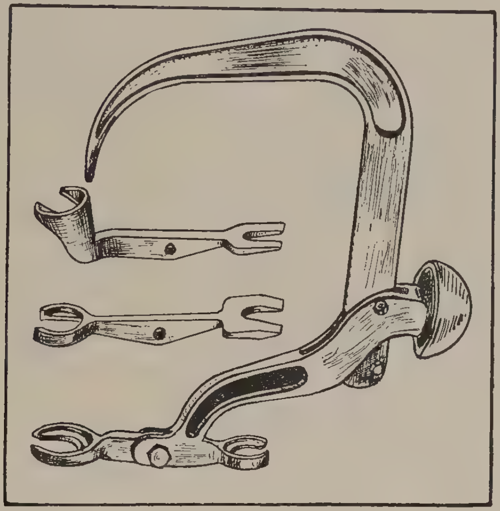


Fig. 139.—The "Apkoway" Valve-spring Tool.

The valve-spring compressor shown in Fig. 139 is equally suitable for many standard side-valve engines. It has three interchangeable dual-fork pieces, one of which is also double sided, so that it is equivalent to four different sizes of lifter. The knob shown on the right-hand side gives a quick action, and a ratchet device on the vertical part of the top lever gives an automatic lock. This tool is known as the "Apkoway" valve-spring lifter.

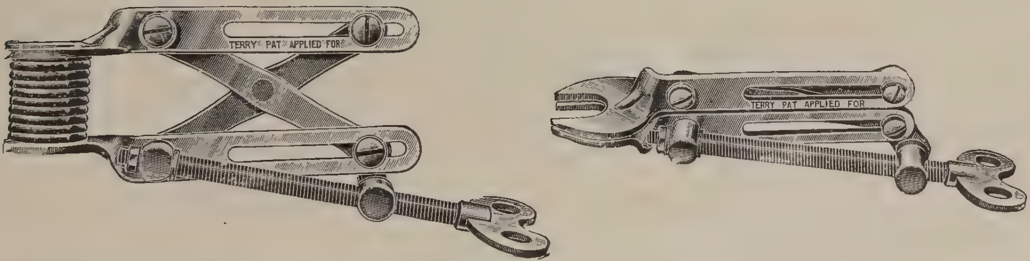


Fig. 140.—The Terry Valve Tool. (*Left*) As used for a Valve-spring Compressor. (*Right*) For Valve-spring Lifting.

Fig. 140 shows the Terry valve-spring compressor, which can be used either for lifting the valve collar and spring, or for compressing the spring prior to its replacement on the engine—as shown in the left-hand illustration.

It is *important when using valve lifters* to avoid bending the stems of the valves; it is quite easy to do this with some of the powerful valve-spring compressors on the market. The spring should be compressed evenly, so that, instead of the spring collar moving in an oblique or tilted position, it moves parallel to its original position and does not strain the valve stem.

It is important also to so place the lifter that when the valve spring is sufficiently compressed the valve cotter *is not obscured or masked by the valve lifter*, or is not in such a position that it cannot be removed either with the fingers or aid of a pair of thin flat-nosed pliers.

We shall conclude this account with a few examples of special valve-spring-lifting tools supplied by manufacturers for their own particular engines.

The valve-spring compressor recommended for Austin overhead-valve car and commercial-vehicle engines is shown in Fig. 141. It employs a cam-action lever (shown in operation below) to pull the forked member downwards in order to compress the spring. The illustration shows also the spring circlip A, split cotter B, cotter clip C, and valve-spring locating cup D, as used on the commercial and A40 engines. After the valve spring has been compressed, the circlip A is first removed and then the split cotters B, when the compressor tool can be taken away and the spring and its collar removed.

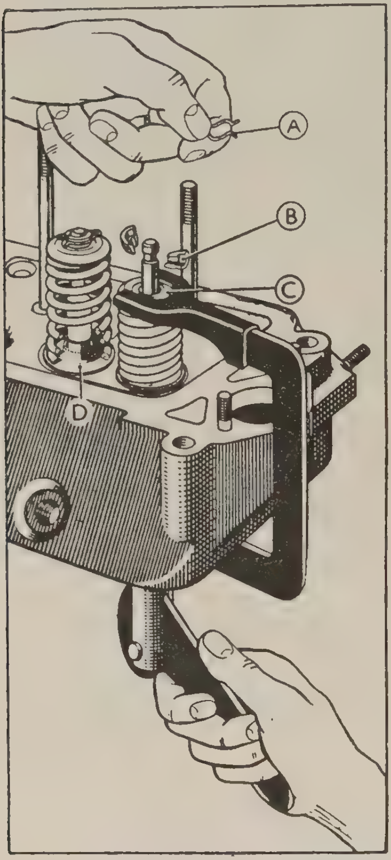


Fig. 141.—The Austin Overhead-valve-spring Tool shown in operation.

In the case of the Standard "Vanguard" engine an original design of valve-spring retainer is employed, rendering spring removal an easy operation. Fig. 142 illustrates the method employed and shows the valve-spring collar above and valve stem below. The former member has an offset hole B, through which the stem of the valve can just pass, and a central smaller hole A, of the same diameter as the recessed portion of the valve stem C. The hole A is countersunk to suit the conical portion D of the valve stem. To remove the collar the inner valve spring is compressed with the tool illustrated in Fig. 143, or it is sufficiently weak to be compressed by hand to enable the collar to be moved sideways for removal.

The tool employed for the Vauxhall Velox overhead-valve springs is the Britool one illustrated in Fig. 144. It consists of three members hinged together as shown. The flat portion of the forked member is allowed to rest on the cylinder head, when movement of the left-hand lever member from its original right-angled position downwards and away from the valves compresses the valve spring and enables the valve cotters to be removed.

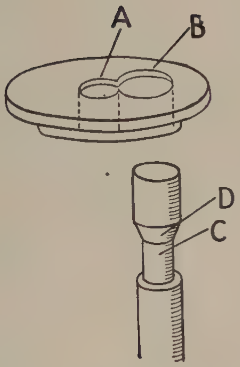


Fig. 142.—The Standard "Vanguard" Valve Collar.

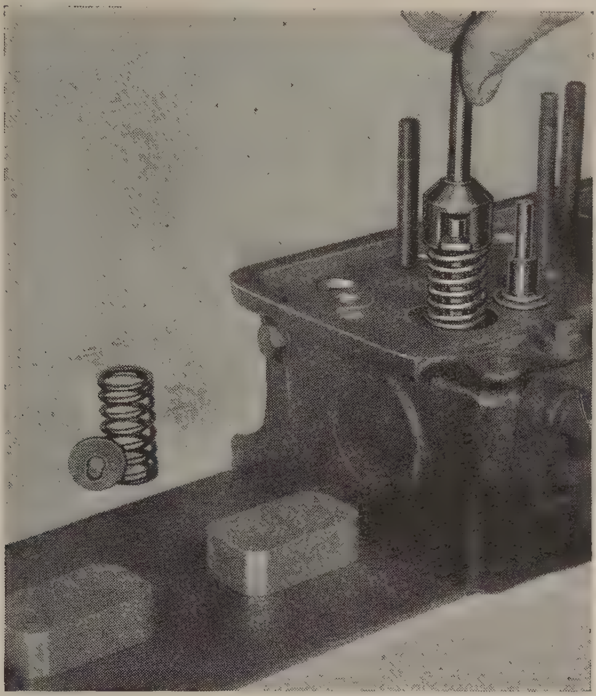


Fig. 143.—Illustrating Method of compressing Standard Valve Spring.

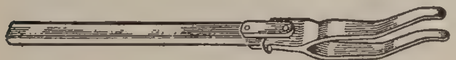


Fig. 144.—Vauxhall Spring Compressor.

Valve-spring Lifters for Ford V-8 Engine

The "Zim" valve lifter shown in Fig. 145 consists of a hexagon steel bar with one end drop-forged into a jaw to fit the Ford springs accurately, and with a thin web to slide between the coils. The inner edge of one

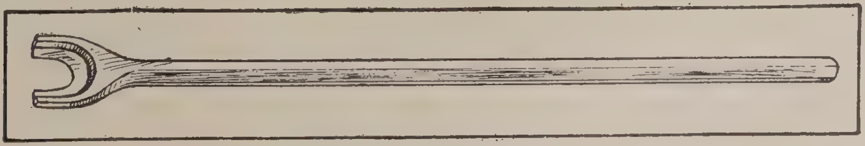


Fig. 145.—Tool for Ford V-8 Engine Valve Springs.

section of the cylinder block is used as a fulcrum in lifting the valve springs in the opposite section. The tool in question is 22 in. long.

Split Conical Cotters

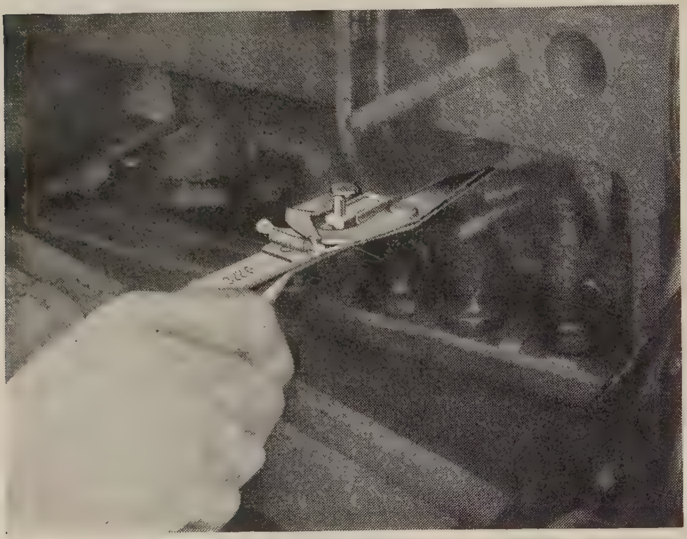


Fig. 146.—Churchill "Cotter Gun" Tool.

The split conical cotter is fairly widely used on account of its simplicity and the fact that it is necessary only to machine a plain groove near the end of the valve stem instead of a hole as in earlier designs. The only drawback to the use of this type of valve collar retainer is that concerned with the fitting and removal of the small half cotters. Special tools in the form of pliers with ends shaped to hold each half cotter are now available for quick insertion or removal of these cotters after the valve spring has been compressed. In the Churchill tool known as a "cotter gun" (Fig. 146), there is a centre slide in which the two halves of the cotter are inserted when this slide has been pushed back to its farthest extent. The end of the slide is then placed against the valve stem where the cotter fits and pressure is applied. The slide then slips back into its normal position and the two arms of the tool hold the cotter on the valve-stem, when the spring and its collar can be released into position and the tool withdrawn.

In an emergency *the type of split-cone cotter can be replaced*, after compressing the valve spring, by using a piece of wood of rectangular section, with its depth equal to the length of the cotter. The end is smeared with thick grease to hold one of the split cotters in order to insert it into the valve-stem recess. The other split-cotter member is replaced in a similar manner and the valve spring is then gradually released so as to allow the collar to grip the cotters.

Another method is to use the magnetised blade of a screw-driver to hold the split cone cotter for replacement.

A special tool for removal and insertion of this type of cotter is also made by Messrs. Terry, Ltd., Redditch.

Fig. 147 shows a useful type of valve tool for replacing split conical valve-spring collars. It is made from a strip of sheet steel cut and bent up as shown in the smaller sketches on the right-hand side. It will be seen that the halves of the collars are held at the bent end of this tool and can readily be inserted once the valve spring is compressed.

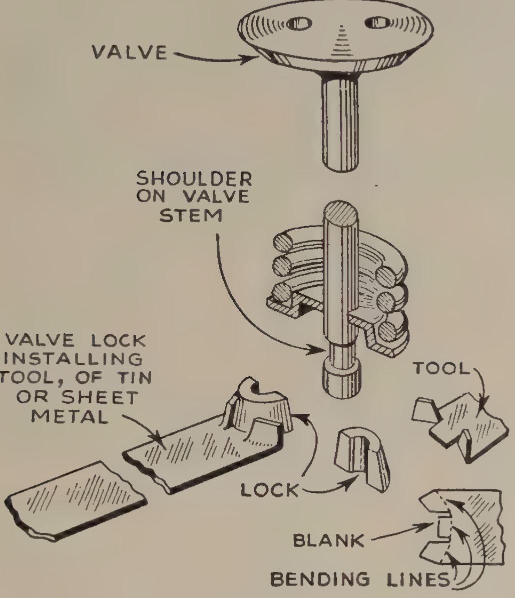


Fig. 147.—Home-made Valve Cotter Tool.

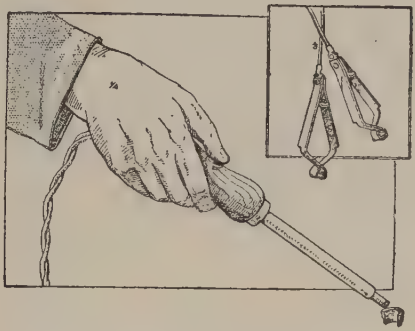


Fig. 148.—The "Kottafinda" Electro-magnetic Device for Valve Collars.

Another useful device, known as the "Kottafinda," is shown in Fig. 148. This is an electro-magnetic tool consisting of a steel member having a wooden handle, which when connected by means of a piece of twin-flex cable to the car battery becomes magnetised and can then be used for withdrawing cotters or split collars of the valves. The use of this device leaves one hand entirely free.

Makeshift Valve-spring Lifters

The ingenious mechanic can usually devise simple lifters to employ in emergencies out of scrap material. Where the removal of valves is of frequent necessity, it is of course much more satisfactory to employ one or other of the special valve-spring lifters supplied for the purpose.

The method illustrated in Fig. 149 suggests a simple makeshift device for valve-spring lifting. It is only necessary to provide a fulcrum for a lever or screw-driver in order to lift the valve collar and spring. As a makeshift a suitable piece of metal, such as a metal nut or piece of hard wood placed on the base of the valve chamber, will usually serve as a fulcrum. Another method is to fasten a piece of strong wire to a convenient nut or sparking plug, and to use a loop of this wire at the lower end as a fulcrum.

Another scheme the author has often employed takes advantage of the

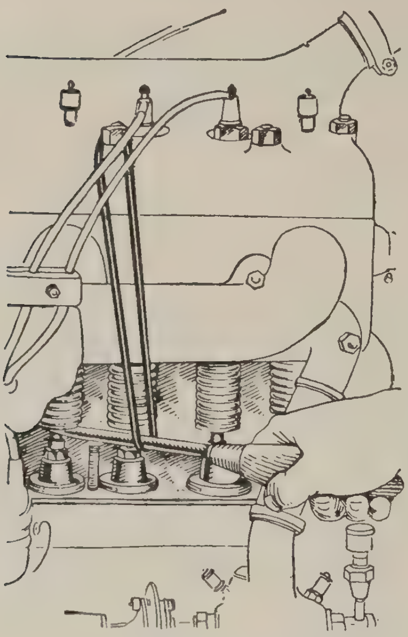


Fig. 149.—A Simple Valve-spring Lifter used on Side-valve Engines.

fact that when the valve is lifted by the cam and tappet the spring is compressed. If a slotted piece of metal tube, or two pieces of rod of equal length, be inserted between the valve collar and the foot of the tappet guide, the valve will remain lifted when the engine is cranked. If now the head of the valve is forced downwards from above, the stem will protrude through the collar sufficiently, as a rule, to enable the cotter device to be removed.

Overhead Valve Springs

It is necessary to remove the rocker arms, and sometimes the shafts, before the springs can be taken off. If the cylinder head has been removed from the engine, it is a comparatively simple matter to remove the overhead valve springs.

One method is illustrated in Fig. 150; it utilises a block of wood, placed between the valve head and table on which the cylinder head is stood, to prevent the valves moving when the springs are depressed with a suitable tool. The block must be shaped to fit the cylinder-head combustion chamber.

In the case of oil engines, where the piston comes within a very small distance of the cylinder head, it is only necessary to turn the crankshaft until the piston of the particular cylinder is on its top dead centre; the

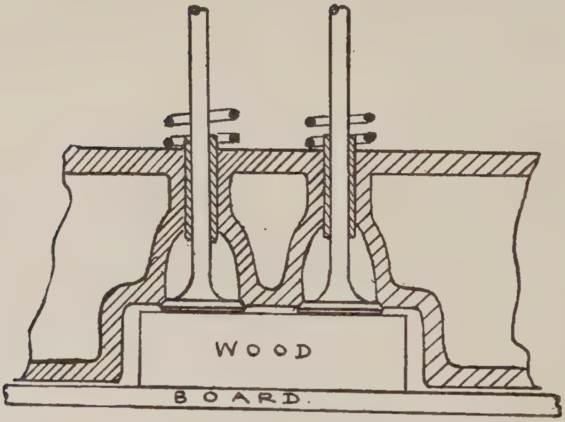


Fig. 150.—Method of removing Overhead Valves.

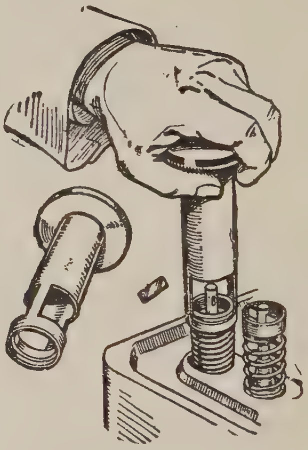


Fig. 151.—The Bradbury Valve-spring Compressor.

piston will then prevent the valve from dropping more than a small fraction of an inch when the spring is removed for replacement purposes.

Fig. 151 shows the Bradbury *overhead-valve spring* compressor and illustrates also the method of using it for compressing the springs. It enables the spring and collar to be evenly depressed, thus leaving free access to the cotter or key. The standard size fits valve springs up to $1\frac{3}{16}$ in. diameter, but additional collars for $1\frac{3}{8}$ in. and $1\frac{1}{2}$ in. are obtainable.

Rolls-Royce Valve-spring Removal Tools

The Rolls-Royce special tools for compressing overhead valve springs are shown in Fig. 152. The procedure is as follows: The locking nut, N1, on the tool should first be unscrewed sufficiently to release a split taper collet which grips the spindle, N2, and the bent portion of the latter inserted through the off-side sparking-plug hole, after which the holder, N, should be screwed into position. The spindle should then be turned and simultaneously pulled away from the head, so that it is bearing in the hollow of the appropriate valve head as shown in the illustration, and the locking nut, N1, tightened while holding the spindle in this position by means of the tommy-bar, N3.

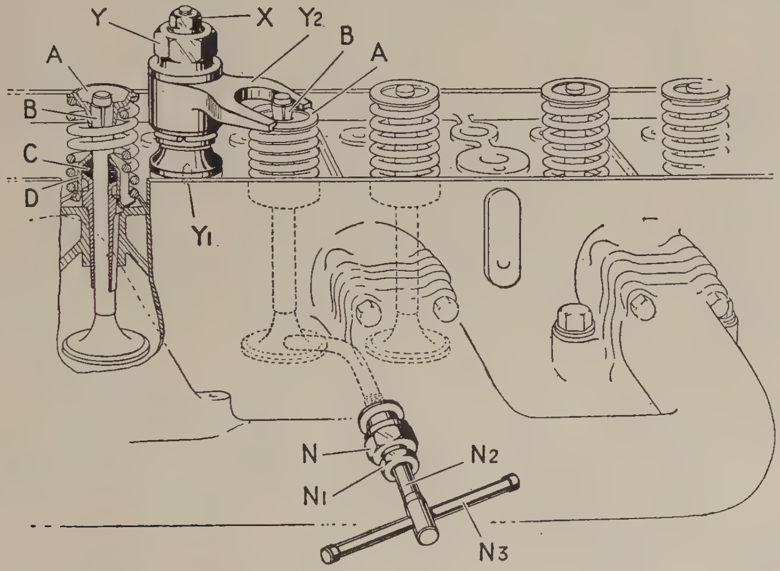


Fig. 152.—Rolls-Royce Overhead Valve-spring Compressor.

The outer sleeve, Y, of the compressing tool should now be unscrewed and removed from the inner sleeve, and the latter slipped over the rocker pedestal stud adjacent to the spring to be removed. It should then be secured in position by one of the nuts, X, belonging to these studs, care being taken to see that the dowel pin, Y1, on the lower end of the holder fits the hole in the facing on the head.

The outer sleeve, Y, should next be screwed on and the jaw, Y2, arranged on the valve washer as shown. When tightening the sleeve, Y, the spring washer, A, may not leave the split taper sleeve, B, readily, but if the washer is given a sharp tap it will free itself.

The locking nut, N1, should then be released, a spanner being held on to the holder, N, when the valve may be removed. The lower washer, D, which acts as a packing gland and the felt packing washer, C, can also be removed. The same tools can be used for replacing a valve spring when the cylinder head is in position on the block, the holder being inserted through the sparking-plug hole.

Replacing Valve Springs

A certain amount of trouble may be experienced in the operation of valve-spring replacement, for the springs must be compressed to an appreciable extent—usually to about 30 to 40 lb. compression load, and held compressed whilst the valve and its collar and cotter are replaced. Whilst many of the valve-spring lifters previously described enable the spring to be compressed in place, others are not at all convenient to use.

The valve springs can, however, easily be replaced if first compressed, and held thus during replacement. The simplest method is to insert two separate lengths of string through the spring and to compress the latter to the required amount by placing it between the jaws of a vice and screwing up. When the required compression is reached tie the coils in this position—one piece of string on each side, i.e. diametrically opposite to each other. The compressed spring can now be removed and replaced around the valve stem, and the collar and cotter inserted, after which the string is cut and removed, as far as possible.

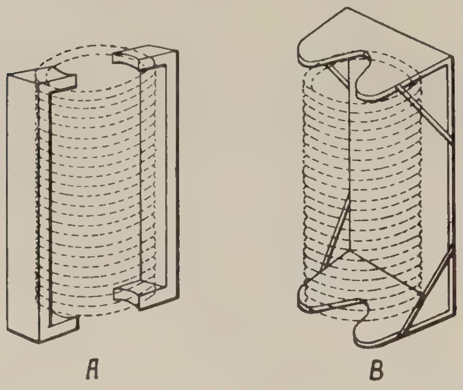


Fig. 153.—Valve-spring Compressors.

A better method is to use two pieces of metal strip bent into a U-shape as shown at A in Fig. 153. These are placed over the compressed spring; the collar can be included to facilitate replacement.

An even better method is to make a spring-compressor fitting of the type shown at B, Fig. 153. This is a one-piece device, which will hold a compressed spring conveniently. It can readily be removed from the engine once the valve and its cotter are in position.

Fig. 154 shows another useful method in which the compressed spring is held between two bent pieces of wire tied with string. After the spring has been replaced—as shown on the left—the string is untied, or cut, and the wire holders prised away.

Fig. 155 illustrates a commercial spring-compressing device. Its action will be clear from the diagrams. The screw handle is used to compress the spring, and the slots in the screw collars shown enable the compressed spring to be tied up with strong twine as indicated in the first and third diagrams.

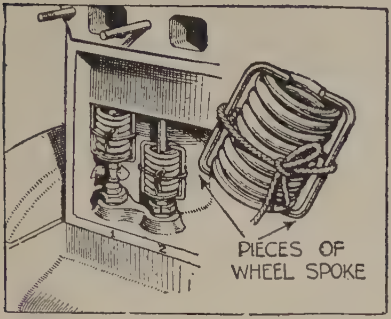


Fig. 154.—Another Useful Valve-spring Replacement Method.

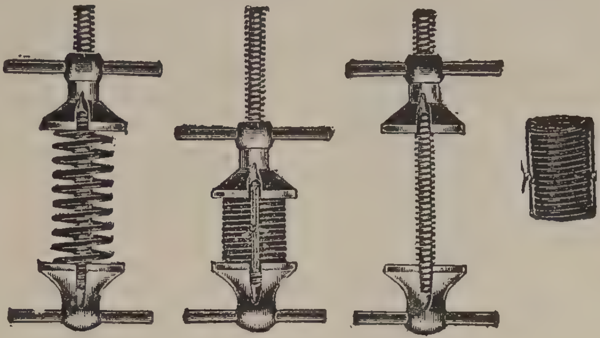


Fig. 155.—Special Spring-compressing Tool.

Testing Valve Springs

After an engine has experienced a good deal of service, the tension of the valve springs may become reduced, so that the valves will not close so quickly; in some cases this reduced spring tension is liable to cause "valve bounce," so that the tappets leave the cams on the camshaft at the higher engine speeds. It is therefore advisable to test the strength of each valve spring before replacing it. This can be done with the aid of a new valve spring, by placing the two end to end, but with a metal washer between, and then inserting the combination in a vice as shown in Fig. 156. Upon screwing up the vice a little, the new and the used springs are compressed. If the latter is the weaker, its coils will close up more than those of the new spring, so that it is possible, by measurement of the lengths of the springs, to determine whether a new spring is required. If there is any appreciable difference in the lengths of the springs when the new spring is compressed by not more than ½ in., the weaker spring should be replaced by a new one.

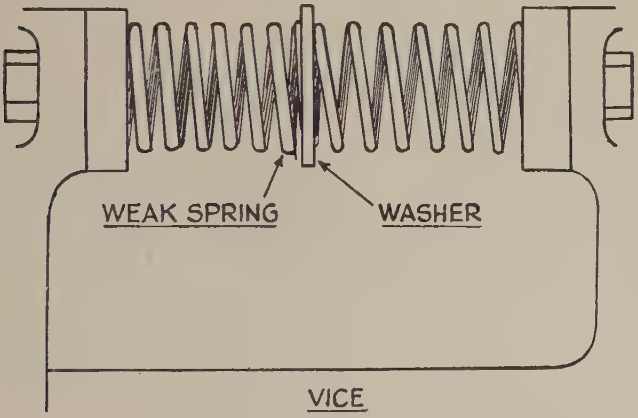


Fig. 156.—Testing Valve Springs.

Routine Servicing Procedure

In the routine servicing of engines of standard design, i.e. mass-production engines, as it would be a rather slow procedure to test each valve spring by the method illustrated in Fig. 156, special methods have been devised to speed up the testing of the springs.

The manufacturers usually specify both the free and the fitted spring axial lengths and the loads required to compress the springs to the fitted lengths. Thus, to take a typical example, the free length of a new Austin A40 engine valve spring is $1\frac{29}{32}$ in., and the fitted length, $1\frac{15}{32}$ in., at a load of 54 lb.

If a valve spring is weaker than a normal one, the load required to compress it to its fitted length will be less than 54 lb., so that the spring should be rejected and a new one used.

A simple form of spring tester can be devised which will apply the load by means of a leverage and indicate it with a spring balance. Fig. 157 illustrates the Britool machine employed by Vauxhall Motors, Ltd., for testing the valve springs of Velox and Wyvern cars. The spring is placed between a pair of plates which are connected respectively to the pressure or load lever shown below and above to a spring balance.

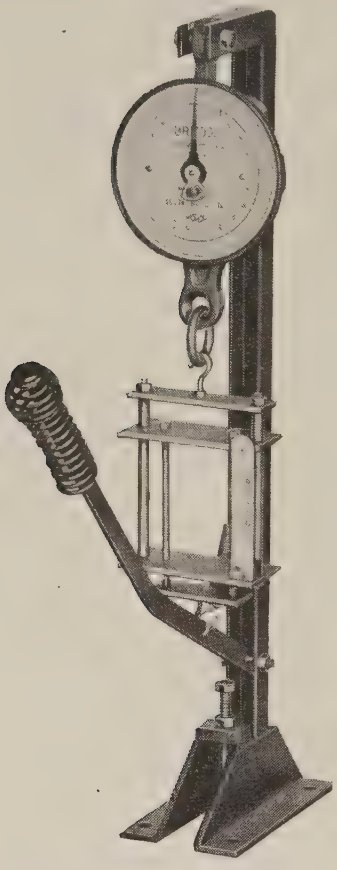


Fig. 157.—The Britool Valve-spring Testing Equipment.

Replacement of the Pistons

This is one of the more difficult operations of engine assembly, not so much in the case of single-cylinder engines but more particularly with four-, six- and eight-cylinder units. The principal difficulty encountered is in connection with the compression of the piston rings to enable the piston to be inserted into its cylinder.

In the normal way the rings, when free, stand away from the piston, as they are of larger diameter. If the piston be pushed into the cylinder the edge of the first ring will come against the flange (or, in the case of detachable-head engines where the pistons are inserted from the top, the top machined surface) and any attempt to force the piston into the cylinder will only tend to break the ring, since the pressure is perpendicular to the "spring" direction.

It is therefore necessary to employ some device to compress the rings in turn, so that they can enter without risk of damage. In the case of small engines of the single-cylinder type it is often possible to compress the rings with the two hands whilst pushing the piston into the cylinder—some engines have a bevelled end to facilitate the compression of the rings.

A good makeshift method in the event of there being no other special facilities is to compress each ring in turn by tying with a piece of string—usually a half-hitch is employed—and then to push the piston into the cylinder, when the ring will readily enter, the string being pushed along the piston. Each ring must be done in turn, so that the process is a somewhat lengthy but, nevertheless, effective one.

With four- and six-cylinder engines two pistons must be entered at a time, so that pairs of rings have to be compressed. A method which the writer has employed with satisfactory results, and which is illustrated in Fig. 158, consists in making a cylindrical clip from steel strip, such that when compressed by means of the butterfly nut shown it assumes the diameter of the piston. With this device, if two or three piston rings are fitted, they can all be compressed at once. A pair of flanges are provided on the clip to bring the latter square on to the cylinder flange or machined surface, to ensure that the piston enters squarely.

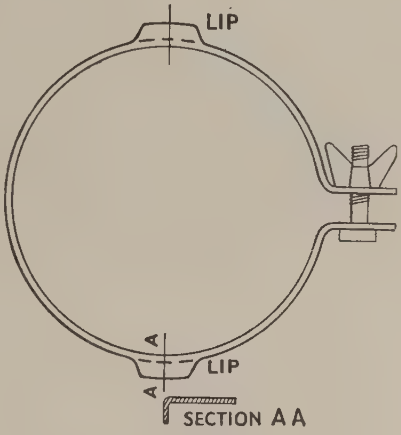


Fig. 158.—Useful Clip used for replacing Piston Rings.

To replace a piston with this device, the three rings (assuming there are three above the gudgeon pin) are spaced so that their slots are in the correct position, namely, at 120° apart, and are then compressed with the clip described, the flanges of the latter being against the cylinder flange. As the piston is pushed into the cylinder, the rings slide along from the clip to the cylinder in turn.

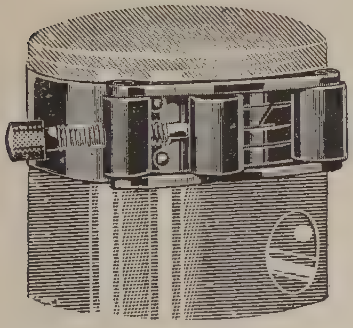


Fig. 159.—Piston-ring Contracting Device.

In using the clip in question, it should be seen that the inside surface is greased to facilitate the sliding of the rings, and that the clip is cylindrical and not screwed up too tight. A little adjustment of the butterfly nut will readily regulate the ring pressure so that the rings will slide in the clip just as in the cylinder.

In most detachable-head-type cylinders the pistons are usually inserted from the tops, one by one; this simplifies the matter of piston replacement, and is a big advantage over the method employed with solid-ended cylinders. The same kind of piston-ring contracting device can be used as in the preceding case, or in an emergency a string or tape-band compressor will overcome the difficulty.

Fig. 159 shows another type of piston-ring contracting device, marketed by Messrs. Brown Bros., Ltd., London. By means of the protruding parts the tool is automatically forced off the piston as the latter is pushed into the cylinder, without releasing the piston rings until they are right inside the cylinder.

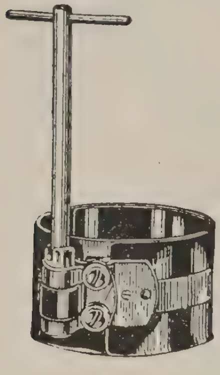


Fig. 160.—Piston-ring Compressor.

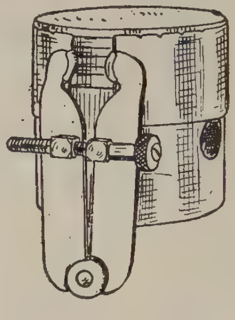


Fig. 161.—Another Tool for compressing the Piston Rings.

Another convenient piston-ring compressor, known as the " Nobby," is shown in Fig. 160. This has a self-locking friction device for holding the rings in the compressed condition. It is adjustable for pistons ranging from 2 in. to 4 in., and it is flared open at the bottom to obviate the possibility of jamming in oversize and chamfered pistons.

A neat and effective piston-ring clamp made in different sizes to suit standard British engines is that known as the Churchill VLC. It has the advantage of enabling the piston to be inserted quickly and without risk of damage to the rings either from the top of the cylinder or from below, i.e. at the crankcase end. One end is bevelled to fit into the recess at the base of the cylinder, and the other is bevelled inside so that the rings are compressed. The piston and its rings are thus inserted with the greatest facility.

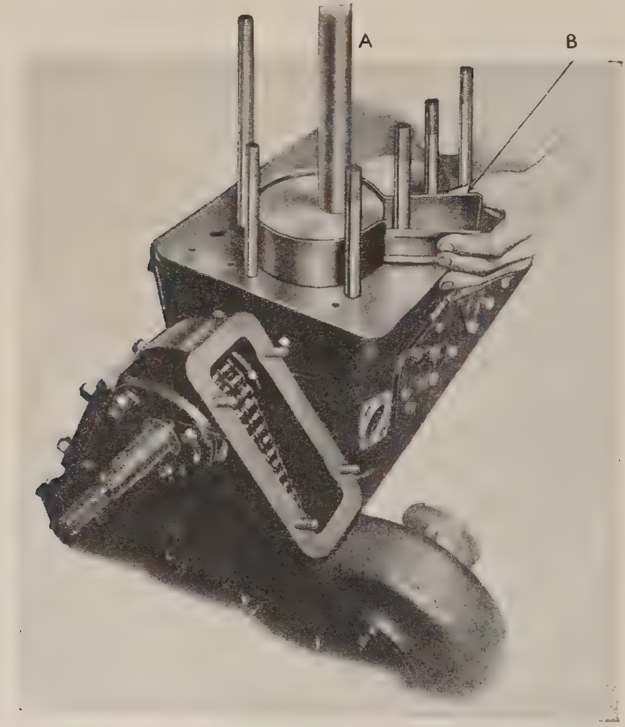


Fig. 162.—Replacing the A.E.C. Oil-engine Piston.
A—Wooden Shaft of Hammer. B—Piston-ring Compressor.

Replacing Oil-engine Piston

A typical example, illustrating the method of replacing commercial vehicle oil-engine pistons after overhaul, is shown in Fig. 162, where an A.E.C. engine piston being inserted into its cylinder barrel is depicted.

The pistons and connecting rods are all numbered in sequence, commencing from the forward end, and should, of course, be replaced in these positions. In order that the piston rings may be inserted into the cylinder barrel easily and without risk of damage, the sheet-metal compressor shown at B is used. The inside of this should be smeared with lubricating oil before it is placed over the piston. When ready for insertion, the top of the piston should be tapped with the wooden shaft of a hammer as shown at A.

Finding the Top Dead Centre

One of the frequent operations with which every garage engineer should be familiar is that of being able to ascertain the exact dead centres, that is to say, the position of the crankshaft corresponding to the highest or lowest positions of the pistons within their respective cylinders. It is very often necessary, for example when adjusting or resetting the ignition or valve timing of a petrol engine, to set one of the pistons on or at a given distance from its top dead centre, the degree of accuracy with which this operation is carried out being dependent on the purpose in question. For example, it is very important when timing the inlet and exhaust valve points of opening and closing to be able to set the crankshaft to within a degree or so of its correct position.

In most of the more recent engines, the flywheel is marked with a line to show the top dead centre (T.D.C.) of the piston nearest the radiator, which is designated No. 1 or $\frac{1}{4}$ or $\frac{1}{6}$ for four- and six-cylinder engines respectively. This mark is brought opposite a fixed mark or a pointer on the crankcase casting (Fig. 163).

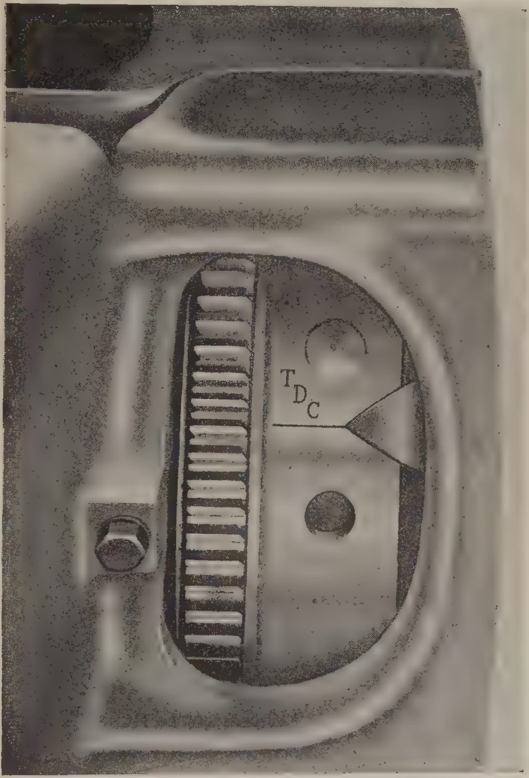


Fig. 163.—Showing Top Dead Centre Mark on A.E.C. Engine Flywheel, with Crankcase Pointer.

Instead of marking the T.D.C. position with the letters "T.D.C." an alternative way is to use a line across the flywheel rim and to stamp or engrave the numbers of the cylinders whose pistons are on their top dead centre positions. A typical illustration of this method is given in Fig. 164, which shows the Austin A40 engine flywheel timing mark which can be seen on removal of the clutch inspection plate. When this line comes opposite a mark on the casing both Nos. 1 and 4 pistons will be on their exhaust top dead centres, namely one on its compression and the other on its stroke (end).

Because it is often inconvenient for the driver mechanic to obtain access to the flywheel casing for ascertaining the T.D.C. positions, some engine manufacturers now make a rule of marking the crankshaft belt pulley rim with a bold line and also the corresponding position on the timing-gear cover plate, as shown in Fig. 165, which illustrates the method in the case of the Morris and Wolseley engines. Although it is not possible to set the T.D.C. position of No. 1 piston as accurately as with the flywheel rim method, it is considered sufficiently correct for ignition timing purposes. In such engines the valve timing is taken care of by other methods that are explained in another section of this publication.

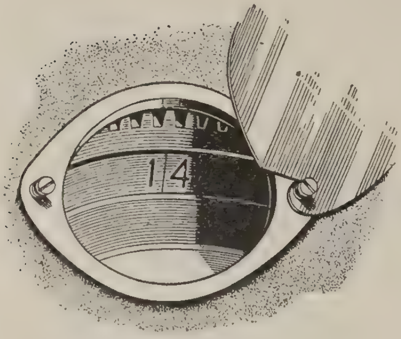


Fig. 164.—Top Dead Centre Mark (Austin).

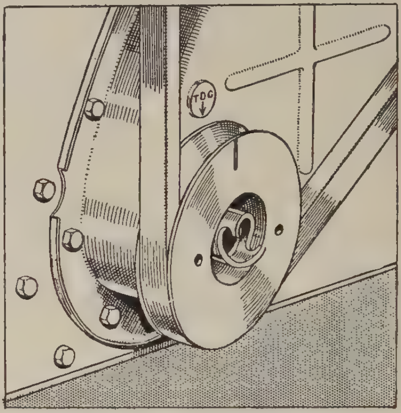


Fig. 165.—Belt-pulley Method of marking T.D.C.

In some instances in addition to marking the T.D.C. of No. 1 piston the flywheel rim is also marked with a line to show the ignition or, in the case of Diesel engines, the fuel-injection commencement point. This arrangement greatly simplifies the timing of ignition or injection, since it is necessary only to set the timing line against the crankcase index or mark by rotating the flywheel by a small amount from its T.D.C. position.

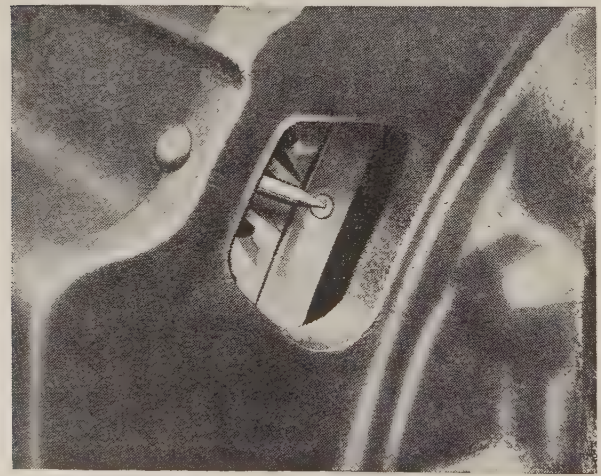


Fig. 166.—Steel Ball T.D.C. Method (Vauxhall).

The Flywheel Ball Method

Another method of indicating the T.D.C. position of No. 1 piston is employed in Vauxhall and Bedford engines as well as certain other makes, namely, by the insertion of a bright steel ball in the side of the flywheel rim (Fig. 166) and the use of a sharp-end pointer fixed to the casing. When the two are in the position shown, No. 1 piston is on its top dead centre.

It may here be mentioned that the polished surface of the steel ball is also used for setting the ignition by the neon-light flashing method.

We shall consider one or two approximate methods of finding the top dead centre first, before passing on to an account of more accurate devices or methods for this purpose.

Other Methods

In cases in which there happens to be a convenient plug over the piston in the cylinder head, it is a fairly easy matter to rig up a simple indicating device, as shown in Fig. 167, A, for showing directly the position of the piston in the cylinder. A pointed rod of metal is inserted in the plug hole—preferably through a short plug having a guide hole to keep the rod vertical—and as the piston moves up and down, the rod moves with it; it is as well to have a tight-fitting collar on the rod to prevent it from dropping into the cylinder on the bottom centre position. Any convenient form of scale can be used to read the pointer's position against. When the piston is near the top dead centre the flywheel should be gently rocked to and fro to facilitate the ascertaining of the top centre position. A more accurate method would be that of substituting a dial gauge (reading to one-thousandth inch) for the scale and to cause the indicator rod when near the top centre position to just touch the dial knob; in this manner (Fig. 167, B) it is possible to obtain dead accuracy.

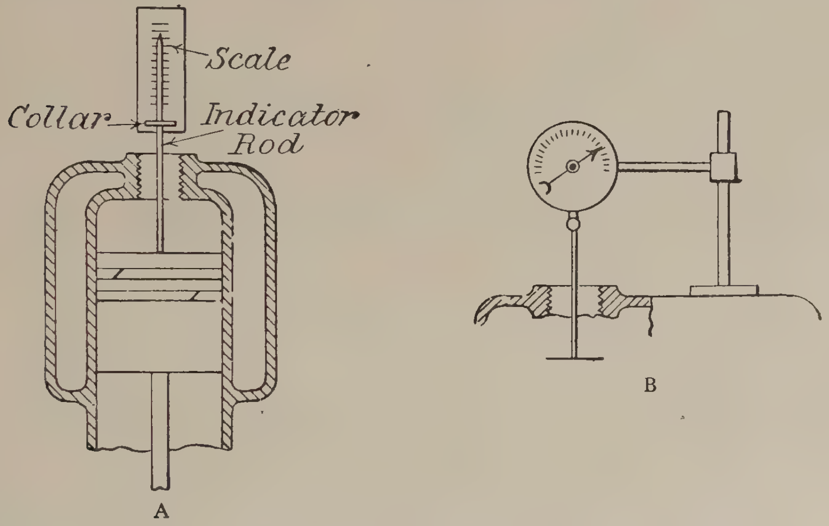


Fig. 167.—Illustrating Methods of finding the Top Dead Centre.

Some motor-car engines, however, have their valves in pockets on the sides of the cylinder heads, as in the case of the well-known L-headed cylinder types, and here it is more difficult to ascertain the top dead centre position, for in most cases the piston cannot be seen or felt with a simple rod device; if, however, the sparking plugs are in the horizontal inclined positions the pistons can usually be observed on removing the plugs, or a simple indicating device rigged up.

A small 4-volt electric pea-bulb on a piece of flexible wire can sometimes be inserted in one of the valve pockets, to show when the piston is on its top centre.

A good method of ascertaining approximately the top dead centre is to use a sparking plug from which the central electrode has been removed so as to leave a small hole. This is inserted in the cylinder to be tested. Slowly turn the engine, listening to the sound of the air " hissing " in or out of the compression tap. When the top dead centre is reached, there will be a point when the air ceases to hiss when the flywheel is gently rocked. This corresponds to the top centre position, and a little practice will enable anyone to acquire skill in obtaining the top centre within a few degrees.

Marking the Dead Centre Position

With indicating devices in which a rod or pointer moves against a graduated scale, it is often better to mark on the flywheel rim the two positions corresponding to equal readings one on the " up " position and the other on the " down " one, and then to bisect the distance on the rim so as to find the exact centre. Having found, by any one of these methods, the top centre, mark the flywheel with a chisel line or ruling and arrange a convenient fixed brass indicator on the flywheel, or a punch or chisel mark on the engine casing to read opposite this. Then, by measurement (using a steel tape) find the opposite dead centre; in the case of a four-cylinder engine the next piston top centre position will give this. Mark this on the flywheel rim, against the indicating mark or pointer. Any other angles can now be set off from these positions, remembering that the circumferential measurement of the flywheel divided by 360 gives the length of arc on the flywheel rim corresponding to one degree.

If it is not convenient to measure the flywheel circumference and you know or can measure its diameter, then multiply this value by the number 3·1416 to give the circumference.

The following formula will be found useful when marking off the flywheel into degree measurements for valve and ignition timing, etc.:

$$\text{Length of one degree on flywheel rim} = \frac{\text{diameter} \times 3{\cdot}1416}{360}$$

If the diameter is measured in inches, the result will be in inches (or fractions of an inch) measurement; if in millimetres, the result will be in millimetres.

CHAPTER 7

VALVE REPAIRS AND ADJUSTMENTS

Valve Refitting and Repairs

ONE of the most frequent jobs which the motor mechanic has to undertake is that of valve reseating and refacing the valves. It is therefore not to be wondered at that a good deal of attention has been given by motor accessory and tool manufacturers to this subject in connection with the provision of suitable tools and appliances for the purposes mentioned. As it is readily possible, however, to reface and reseat petrol-engine valves without any special appliances, and since the ordinary amateur is usually compelled to use the more simple methods, these will be described first. It should, however, be added that the earlier processes described are more tedious, and usually quite unsuited to the purposes of large repair shops, where time and expense are the ruling considerations.

Simple Valve-refacing Methods

It should be explained that after a car has been running for several thousand miles, the valves become a bad fit on their seatings and, in the case of the exhaust valve especially, the seatings become worn and pitted. There is thus a leakage of gas or mixture past the valves whilst the engine is working, which causes a loss of power.

On dismantling the valves and examining them, it will be found that although the inlet valves are bright, due to their being constantly flushed with the wet incoming mixture (and also to their relatively lower temperature), the exhaust valves, which are exposed to a higher temperature and to the passage of burnt oil and carbon particles, are blackened and not infrequently have small depressions or pittings, due to solid particles being hammered between the valve faces and their seatings. Moreover, the heads and stems are usually carbonised. The inlet valves are sometimes rounded a little on their faces, more particularly if there is any play in the valve guides. Sometimes the valve faces have been so hammered that after long usage the width of the seating portion is appreciably increased.

The first thing to do is *to clean the valves* thoroughly. This means a general cleaning off of the carbon deposit, by scraping or brushing with a wire brush. The valve stems and their guides should be cleaned with paraffin before the valves are reground, in the manner described previously.

The carbon on the stems can conveniently be cleaned off by means of a strip of emery cloth wrapped partly around the stems and pulled to and fro. When cleaning the carbon off the valve heads with a knife or scraper, do not scratch the seatings at all, and remember also to remove the carbon around the periphery of the valve head. The carbon from around the valve seating in the cylinder can be removed at the time the cylinder is decarbonised, remembering to clear it out from *under* the valve seatings.

Each valve head should be numbered as described in an earlier chapter of this volume, for it is important that each valve should be replaced in its original position. Next, starting with the inlet valve—which is easier to reface than the exhaust—smear the working face of this with a valve-grinding paste of the *fine* variety or grade—a good paste for this purpose is the Clover compound. Replace the valve on its seating and, if the valve head is slotted, turn or grind the valve head with a steady pressure. The valve should *not be rotated continuously*, but with a reciprocating angular motion, occasionally moving the valve round to another position.

The valve should be lifted now and again, and the grinding compound smeared over evenly, at intervals. After a time remove the valve, dip the head in a small tin of paraffin, wipe, and examine. When the whole area of the inclined face is quite bright and free from markings of any kind, it is in the proper condition for replacing in the engine. The seating should then be cleaned thoroughly with paraffin and a rag, and all traces of the grinding compound removed from around the cylinder seating. The seating, also, must be free of pitting marks. It is a good thing, when this has been done, to dip the head of the valve in clean paraffin, and to repeat the grinding operation; this results in a well-polished seating and valve face.

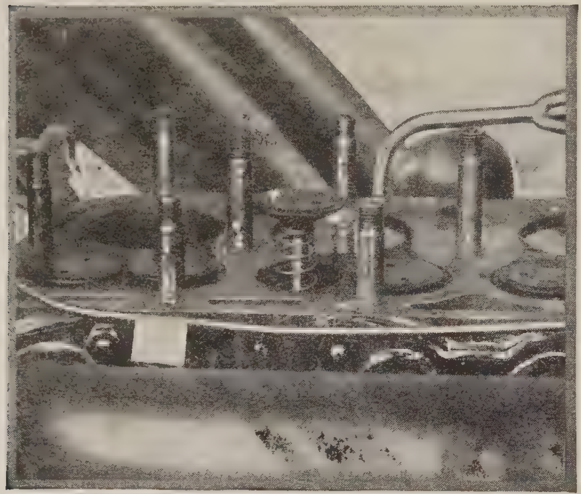


Fig. 168.—Using a Light Spring under Valve Head when Grinding In. (Shown on Morris Engine.)

After each inlet valve is ground in and cleaned, it should at once be replaced, with its spring, collar, and cotter pin, in the cylinder, so as to exclude dirt from the seatings.

In the case of the exhaust valves, these will require more physical work, and if much pitted, it is better to use a *coarser* grade of grinding compound to commence with, so as to remove the material of the faces more quickly, finally finishing with the finer grades. If the exhaust-valve faces are badly pitted it will be better to have them refaced in a lathe; this takes only a short time, and saves a good deal of tedious grinding; moreover, it saves the cylinder seatings.

We shall describe later special tools for refacing valves, but up to the present we have assumed that the amateur is without these.

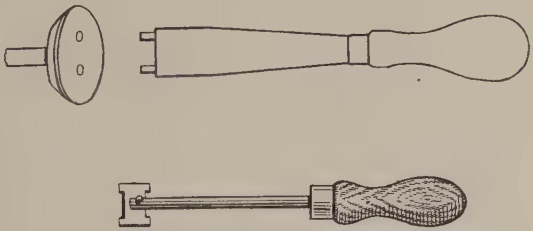


Fig. 169.—Valve-grinding Tools for Two-pin Heads.

If the valve faces are found to be too wide after regrinding, it may be necessary to reduce their width by turning in a lathe or by judicious filing—the latter method is not recommended, however. The usual width of valve face for a 12- to 15-h.p. engine is about ⅛ in. When finishing the facing and seating of a valve, after all marks have been removed, ordinary domestic metal polishing paste, or Bluebell polish, may be employed to give a fine finish. When the valves have two small holes drilled in their heads instead of a slot for turning, it is necessary to make or to obtain a special tool (Fig. 169) for grinding them in. Such a tool can readily be made from an old file or a strip of mild steel—usually 1 in. by ⅛ in.—filed so as to leave two tapered pegs as shown.

Electrolytic Method of Valve Cleaning

In connection with the large-scale servicing of motor-vehicle engines, where appreciable numbers of valves have to be decarbonised or reseated, a method developed in the U.S.A. may be adopted with satisfactory results. The valve to be decarbonised is first degreased and then placed in a bath of molten caustic soda, 60 parts, and sodium carbonate, 40 parts. Sufficient heat should be applied to maintain the salts in the molten condition. The valve is connected to the negative lead of a 6-volt source of direct-current supply, the positive lead being a metal plate immersed in the bath. A current of about 6 amperes is passed through the bath for about 2 to 5 minutes. After removing the valve from the bath it is placed in water and the solid caustic soda dissolved off, after which any remaining deposit is brushed off with a brass wire brush. No loss of metal of the valve occurs during the process and the latter is left quite clean.

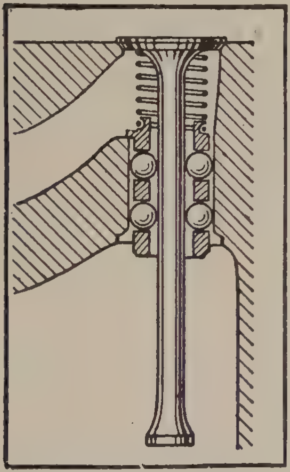


Fig. 170.—The Churchill VLC False Valve Guide.

False Valve Guides

It is very important when regrinding valves to their seatings to ensure that the seating is absolutely concentric to the axis of the valve guide; otherwise it will not be possible to obtain a gas-tight seating. If the valve guides have been removed from the cylinder block, it is advantageous to employ a false valve guide, such as the VLC design illustrated in Fig. 170. This has a cage containing eight ball bearings, which fits into the valve-guide hole and ensures the valve stem being truly coaxial with the guide hole. The head and seating are therefore concentric with the guide-hole axis.

Valve Regrinding Tools

The simplest and most convenient tool for regrinding ordinary slotted-head valves is the screw-driver; a large size will be found best for the purpose.

A screw-driver head fitting in an ordinary drill brace will also save a good deal of time, but the valve must not be rotated much in regrinding, but rather reciprocated. If a spring is placed between the valve head and the cylinder casing, so that the valve is lifted off its seating when the pressure is released during grinding, this will avoid having to lift the valve by hand every now and then. An ordinary carpenter's brace can be used for valve-grinding purposes, and a reciprocating movement given conveniently. As a fair amount of end pressure is required when grinding between the valve and its seating, it is as well for the worker to be well over his job; if the engine is arranged at about 2 ft. from the floor of the garage, this will be found to give a convenient working position.

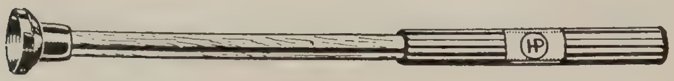


Fig. 171.—The H.P. Suction-type Valve-grinding Tool. The valve head is gripped and held by suction.

The useful valve-grinding tool shown in Fig. 171 employs a rubber suction cap attached to a wooden rod about 12 in. long provided with a serrated rubber sleeve at its other end to act as a grip. In this case the rod is used in a similar manner to an ordinary screw-driver, when the latter is employed for valve grinding. As in the preceding case no spring is required under the valve head. An improvement, shown in Fig. 172, consists of a rubber suction cup attached by means of pitch or Chatterton's compound to the screwed chuck stem of a small hand-drilling machine of the inexpensive type sold by chain-store firms. The suction cup is attached to the valve head, gripping this securely so that the valve can readily be ground back.

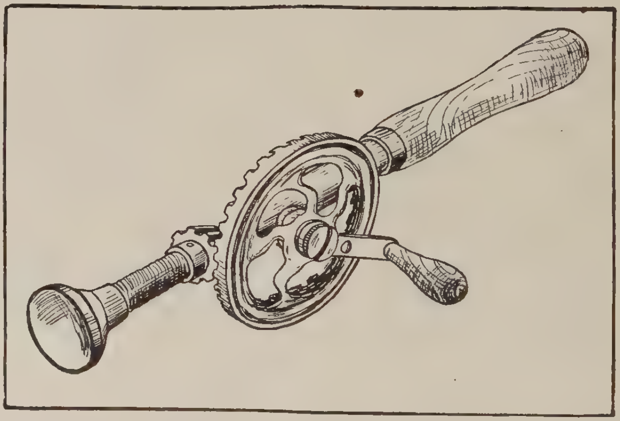


Fig. 172.—A Suction Cup mounted on Hand-drilling Machine Spindle for Rapid Valve Grinding.

wards and forwards by rotating the handle of the drilling machine in either direction. Upon lifting the drilling machine the valve is lifted also, so that there is no need to use a light compression spring under the valve head.

The method of using the suction-type valve-grinding tool is illustrated in Fig. 173, which shows the Austin A40 cylinder head and a suction-pattern tool in action. This tool has a cylindrical shank, which is rotated to and fro during the valve-grinding action. It may be mentioned that the valves used in this case are of the overhead type and have no slots or peg holes, so that it is essential to employ a suction type of tool.

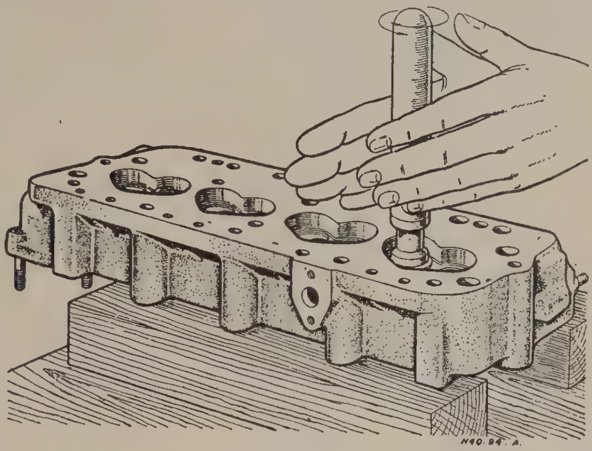


Fig. 173.—Method of using the Suction Cup Valve Grinder (Austin).

Grinding-in Overhead Valves

Although some of the methods described in this chapter are readily applicable to overhead as well as to side valves, it is often more convenient to employ a tool which holds the valve stem, instead of one engaging with the valve head. Thus the Armstrong-Siddeley overhead valves are

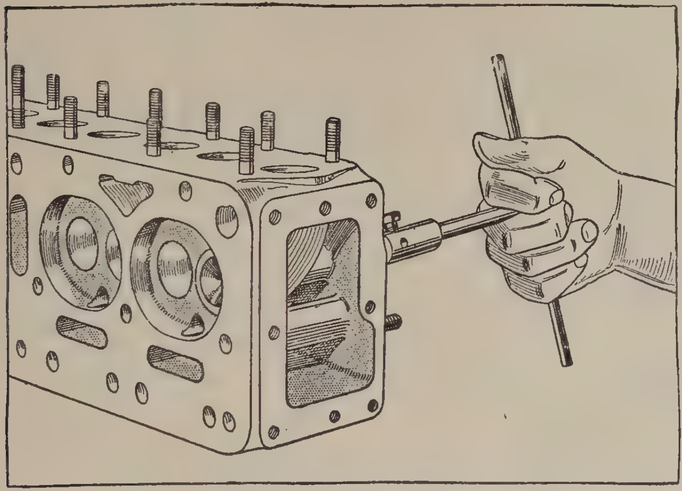


Fig. 174.—The Armstrong-Siddeley Valve Tool.

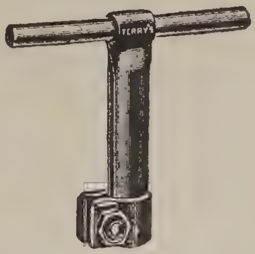


Fig. 175.—The Terry Overhead Valve-stem Tool.

ground in with the T-headed tool shown in Fig. 174; this tool is supplied by the makers. The head of the tool is locked to the valve stem by means of a set-screw and the valve is then ground in, in the usual manner. The makers recommend grinding the valves in at 5,000 to 10,000 miles intervals, using Richford's medium and fine grinding paste thinned with oil.

The Terry valve-stem holding tool (Fig. 175) operates on a similar principle to that shown in Fig. 174.

Special Valve-grinding and Facing Tools

Although, as we have stated, it is possible to reface valves by the method of grinding them into their seatings, it is a relatively slow process compared with that of employing a special tool designed for the purpose.

If the exhaust valves of a six-cylinder engine, say, happen to be badly pitted, the grinding method of obtaining a new face on each valve will be found a somewhat laborious one, and it will often repay the amateur mechanic or motor owner, who does his own overhauls, to procure one of the valve-facing tools or machines on the market.

In selecting such a tool, after assuring himself that the angle of the seating (or facing) is correct, he should make sure that the cutter or cutters will work without chattering, and that a perfectly clean cut is taken, leaving no tool marks or inaccuracy of facing.

Further, the valve-stem guide of the tool should either be adjustable or interchangeable for different diameters of valve stem, and there should be no play in the guide. The simplest form of valve refacing tool is that in which the valve is held in a guide so that it can rotate without play, and possessing a single hardened tool-steel cutter affixed at the proper angle.

There is a stop of the adjustable type which is held against the head of the valve. The valve stem is then rotated, by means of a clamp-lever or carrier, similar to a lathe carrier, in the direction of cutting.

Valve Angles.—It is necessary to know the correct valve-seat angle before attempting to reface a valve. In this connection it may be stated that the two popular valve-seat angles are 30° and 45°, each manufacturer having his own preference. In a few cases modern car engines employ a different angle for the inlet and exhaust valve, namely 30° for the inlet and 45° for the exhaust valve.

In the absence of information on these angles the reader should consult the data volume that is issued with this work.

Typical Valve-refacing Tools

A type of single-cutter valve tool is shown in Fig. 176. This is known as the K.B. valve tool, and is made by Messrs. Mansions Motors, Ltd., London. In this case the arrangement resembles that of the ordinary metal-turning lathe, for there is a valve-rotating device and a cutting tool fixed in an adjustable tool holder (seen in the upper left-hand side of Fig. 176). The valve stem fits in a standard bush, and is held secure by means of grub screws. A series of nine such bushes is supplied, all of the same outside diameter but with different sizes of holes to suit the valve stems; the latter range from 10 mm. downwards. In addition there are eight bushes ranging from $\frac{5}{16}$ in. upwards for larger vehicles. It will be observed that the tool angle is adjustable to suit any angle of valve face.

The maximum diameter of valve head which this tool will cut is 3 in. The valve is rotated against the cutting edge of the tool, an adjustable screw top—this time on the foot of the valve—being provided to regulate the feed or cut. A valve may be refaced in a matter of 1 to 2 minutes.

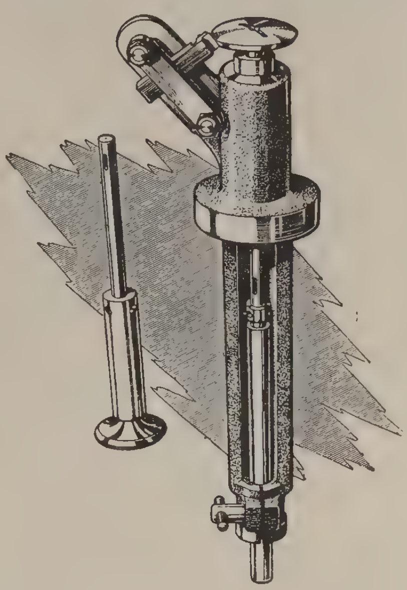


Fig. 176.—The K.B. Valve Tool.

We shall next describe another type of valve tool of the multiple-cutter pattern, in which there is a number of cutting edges arranged around the surface of a conical depression in the tool. Such a tool possesses the advantage of being self-centring, and, having a number of cutting edges, does not chatter or produce tool marks; moreover, it lasts much longer. It is a straightforward matter for the keen amateur to make such a tool if he has a lathe. It is only necessary to turn a conical surface at 45° or at the special valve-face angle to the axis, and with a suitable file to cut out the metal so as to leave a suitable cutting edge on each toothed portion. A hole must be bored to suit the size of valve stem, or a large hole with interchangeable bushes may be used. The tool should then be hardened right out in luke-warm water or oil and tempered to a straw colour.

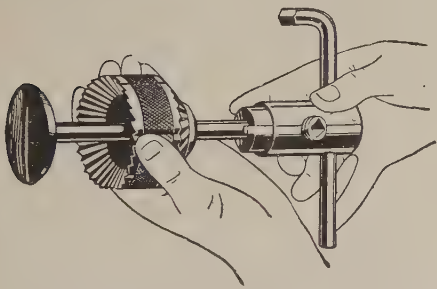


Fig. 177.—The J. & S. Valve Truer.

Fig. 177 illustrates the J. & S. hand-vice pattern valve-truing tool. In this case the cutter unit serves the dual purpose of valve and cylinder seating tool; the external conical cutter is for the latter purpose.

The valve to be trued is placed with its head in the cutter, and the two are inserted in the casting, or vice, shown. An adjustable spring (not shown) bears on the head of the valve, and gives the necessary pressure for cutting. If the valve face is of hard material, it may be necessary to employ more pressure on the head of the valve; this is accomplished by screwing down the knurled head on the right.

The valve is rotated by means of the carrier shown on the right, and if the cutting pressure is correctly regulated in the first instance, the cut gradually diminishes until the tool ceases to cut. This gives a fine surface and an excellent finish to the valve.

The same firm[1] also make other patterns of multiple-edge valve-facing and reseating tools, including a simple and a combination type.

Facing Valves in the Lathe

If a small lathe is available, pitted or worn valves may be restored to new condition by taking a light skim with a suitable tool across the valve face.

The valve should, preferably, be held by its stem in a collet-type chuck, as this ensures concentricity of the valve head with the axis of the lathe spindle, and at the same time there is no risk of injury to the valve stem as may happen when a self-centring chuck is used.

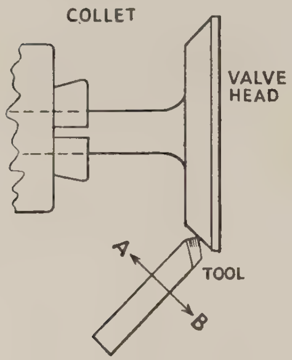


Fig. 178.—Truing Valve Face in the Lathe.

The stem should be gripped fairly close to the head (Fig. 178) to minimise vibration or deflection under the tool pressure. It is always advisable to check the valve stem for any bending effect before placing it in the chuck.

The high-speed-steel tool used should have a top rake of about 15°, side rake of 5°, and front and side clearances of about 6°. The lathe spindle should rotate at a speed that will give the tool a linear cutting speed of about 60–80 ft. per minute. Thus if the valve head is of 1¼ in. diameter it should be run at about 250–330 revolutions per minute.

The tool should traverse the valve face as indicated by the direction AB (Fig. 178). For this purpose the slide rest of the lathe must be rotated to the appropriate angle. Only a very light cut should be made, so that the minimum of metal is removed. Use a fine feed and a sharp tool for finishing; a cutting lubricant will give the best finish.

Typical Example of Regrinding Car Engine Valves

The following is a detailed account of the procedure recommended for grinding in the valves of the Austin 10-h.p. engine: Access to the valves is achieved by the same dismantling procedure as for decarbonising. Drain the radiator, remove the bonnet sides, disconnect a battery terminal and remove the dynamo, air cleaner, sparking-plug leads, and cylinder-head nuts. Remember to ease off the cylinder-head nuts a little at a time in the correct order, and if it is felt that more working room is desirable, the bonnet lid may be removed complete by detaching the four bolts securing it to the hinges.

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[1] Jones & Shipman, Leicester.

At this stage it is advisable to examine all the valve seats while the engine is rotated to open each valve fully in turn. Where the valve seatings show signs of severe pitting, i.e. have black pin-prick holes in them, it will be necessary to use a valve reseating cutter for compression to be restored.

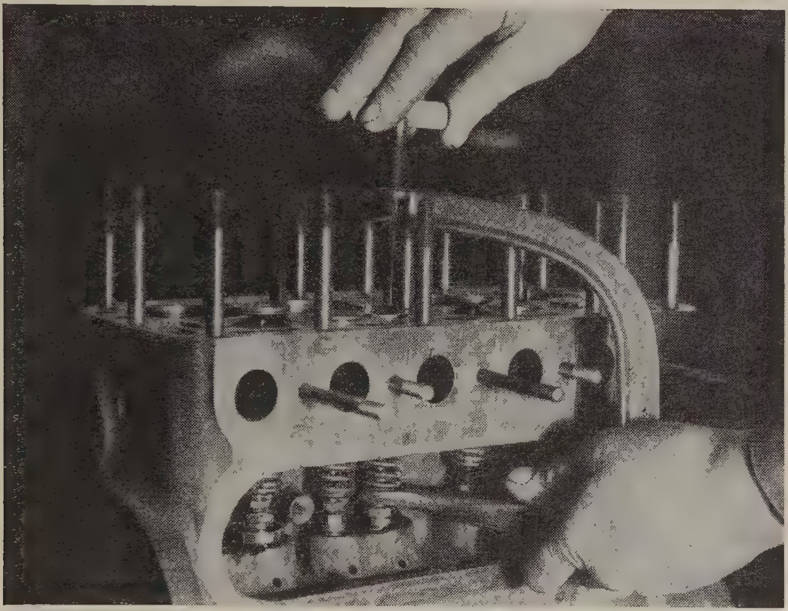


Fig. 179.—Showing Use of Valve-spring Compressing Tool, for removal of the Split Cotters and Valve.

However, with an engine that has been well maintained and driven with reasonable care, the valve seatings should present a fairly even surface marked only with dull grey or black streaks, and compression may be completely restored by the normal grinding in of the valves, which is a simple operation, requiring no special skill or equipment.

Next disconnect the choke and throttle controls at the carburettor, the petrol pipe to the carburettor at the petrol pump, the vacuum pipe to the carburettor, and remove the nuts securing the exhaust pipe to the manifold. The exhaust pipe should then be pushed downwards until free of the manifold mounting studs and the copper-asbestos jointing washer left in a safe place.

The manifold, complete with carburettor, may be lifted away from the engine when the five mounting nuts have been unscrewed from their studs. When removing the manifold-joint washer take care not to damage it, and if necessary ease it free of the engine with a sharp thin knife. Access to the valve springs and cotters is now obtained by removing the valve side cover complete with breather downpipe and jointing washer.

The two holes connecting the valve chest with the crankcase should be closed with clean rag before any attempt is made to remove the valve cotters, otherwise a cotter or two may find their way into the engine sump, thereby entailing much extra work in retrieving them.

When using the valve lifter (Fig. 179) first make sure that the valve is fully closed and place the lower arm of the tool securely under the valve-spring cup. Hold the lifter firmly towards the engine while winding down the screw on to the valve head and immediately the cup lifts sufficiently and the two split valve cotters can be removed, release the screw. Then fit the lifter to the next valve and repeat the operation until all sixteen individual valve cotters have been removed.

When the engine is built, all valve heads are numbered from one to eight, commencing at the front of the engine, and it is essential that the valves are kept in this order. Any number that has become obliterated, or is missing entirely, as may happen if a new valve has at some time been fitted, should be scratched on the valve head before the valve is removed from the engine. This will prevent confusion arising as to the correct order of refitting.

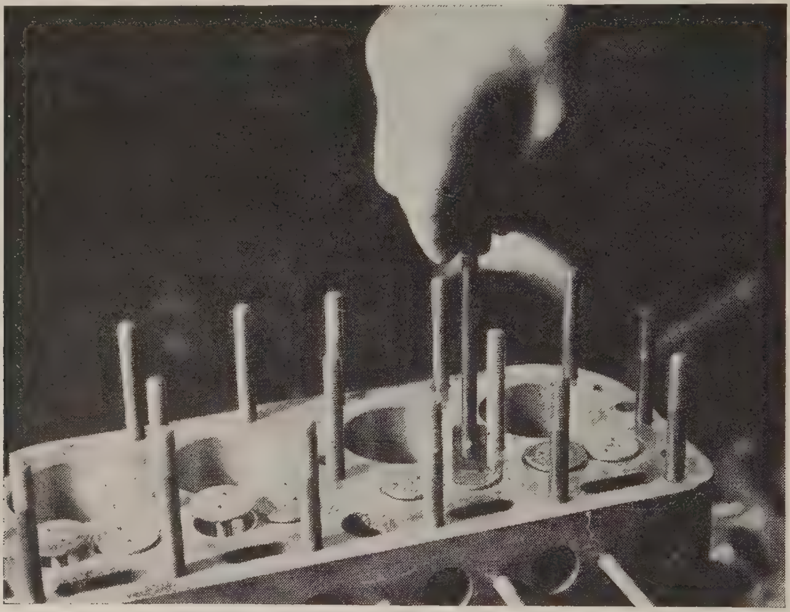


Fig. 180.—The Grinding-in Operation, using Special Valve-head Turning Tool.

Lift each valve from the engine in turn and carefully examine the head. If it is found that the angle of the valve face forms a sharp edge with the top of the valve, indicating previous regrinding, the valve must be renewed. Before regrinding the valves, spring out the valve springs and cups from the valve chest and screw down all the tappet heads two or three turns to give plenty of clearance to the valve-stem ends. To alter the setting of the tappets the special locking plate must first be inserted between the two tappets to prevent them from turning while the lock-nut and screw are turned with the spanners (Fig. 183).

The valves should be refaced on a valve refacing grinder, if they are pitted. Otherwise regrind first with a little coarse grinding-in paste, using the special peg fitting tool, in the manner described elsewhere in this chapter. When a smooth matt finish has been obtained, clean off the old paste, smear a little medium-grade paste on to the valve face and continue regrinding. *A good check on correct valve grinding,* after cleaning off the paste from the valve seating, is to mark the latter in about five different places with a lead pencil (Fig. 181). Then replace the valve and rotate it for about a quarter of a revolution. Remove the valve and if, on examining its seating, it is found that all five pencil marks have been obliterated then the seating and valve face may be considered quite satisfactory; otherwise continue regrinding with the medium paste until this result is achieved. After regrinding, remove all traces of the paste with a little paraffin, making sure there is none under the valve heads or on the guides or valve stems (Fig. 182).

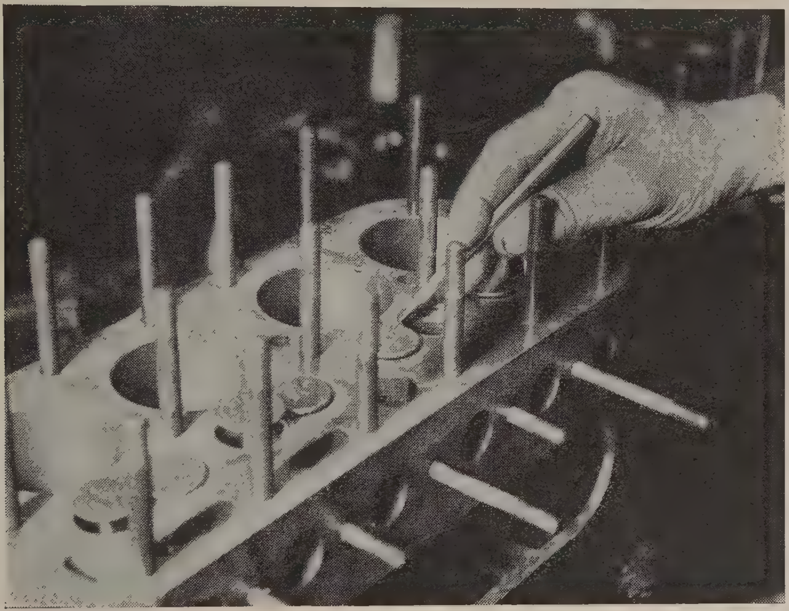


Fig. 181.—Illustrating the Five Pencil Marks Method of testing for Perfect Valve Seating.

The valves and valve springs should now be reassembled. First, spring the valve springs and cups into position in the valve chest. The valves are then lowered into position and the valve cotters replaced with the aid of the valve-lifter tool, reversing the removing operation as described previously.

Finally, when all the valves are in position all the tappet screws must be reset to give the *correct tappet clearance* of ·012 in.; make certain that none of the valve cams is actually lifting the valve when resetting the clearances. Use the tappet locking plate to prevent the tappets from rotating and screw up the tappet screw so that it only just nips the feeler gauge against the end of the valve stem. The tappet screw must now be held in position while the locking nut is tightened down (Fig. 183).

When all the tappets have been adjusted and locked by their nuts, replace the valve side cover complete with the joint washer, making sure that the breather holes to the crankcase are quite clear. Assembling is then a matter of reversal of the dismantling procedure.

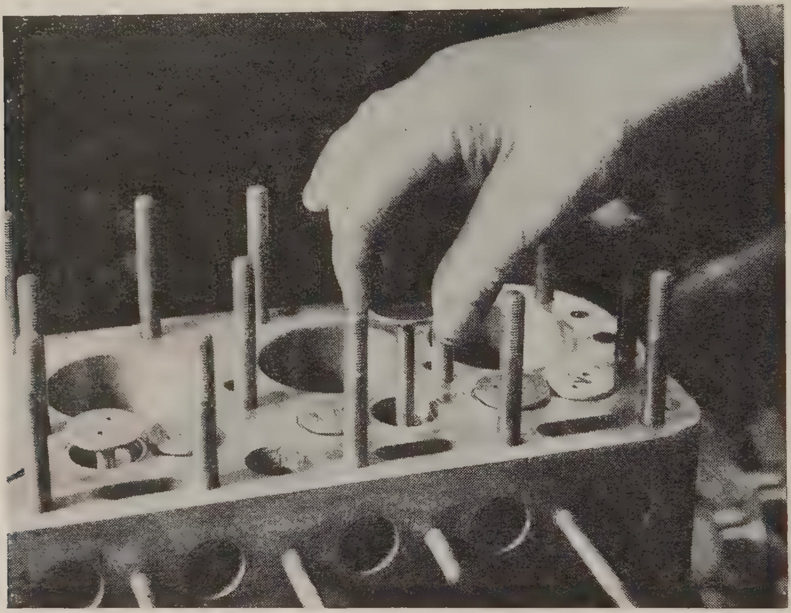


Fig. 182.—Cleaning Valve Head and Stem with Paraffin after Regrinding. The Stem is dipped in Paraffin and rotated in its Guide to clean the Surfaces.

The cylinder-head gasket must be fitted *with the beaded face downwards*, and it is a good plan to smear both sides of this gasket (and also the manifold gasket) with jointing compound before replacing them on the cylinder block.

Tightening of both the manifold and cylinder-head securing nuts must be done carefully by *working from the centre outwards* and tightening each nut a little at a time, and after a short run has been made both the cylinder head and manifold securing nuts should be rechecked for tightness.

The sparking-plug leads must be replaced in their correct firing order—1, 3, 4, 2, with number one cylinder at the front. The cylinder number will be found stamped on the brass terminal at the end of each plug lead.

Two remaining points are worthy of special mention. First ensure that the choke control wire is correctly connected to the carburettor. The choke flap must be fully open when the choke control on the dash is closed and the choke flap must fully close when the choke is pulled out to its full extent. Finally, make sure that the fan belt is correctly tensioned to have one inch of lateral movement, and that all water-hose joints are leak-proof.

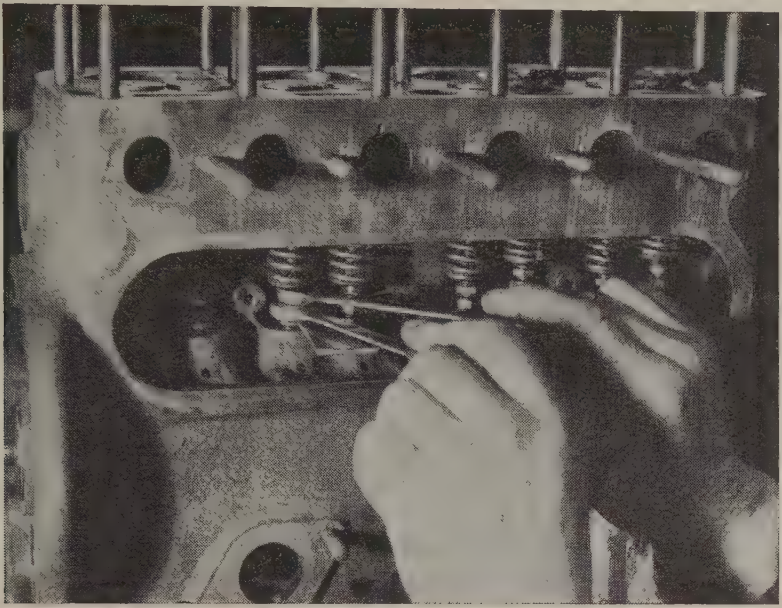


Fig. 183.—Adjusting Valve-stem Clearances, using the Special Tappet Locking Plate to prevent the Barrel Tappets from turning during Adjustment of the Tappet Screw.

After fulfilling all these requirements the user will naturally be anxious to check what improvement he has been able to achieve in the compression, and thereby in engine performance. For the first few miles, until the engine has settled down, this may be disappointing. But after twenty or thirty miles' running, a check of the compression of each cylinder by turning the engine over by hand should give satisfactory results, and it is at this period of service that a check-over once more for tightness of the cylinder-head and manifold nuts, and the hose connections of the cooling system, is desirable.

Valve-grinding Machines

For the routine servicing of petrol- and Diesel-engine valves the re-facing of pitted or grooved valve faces by the grinding method gives the quickest and most satisfactory results. Hitherto valves have been refaced in the lathe, using a high-speed grinder attachment, but it has since been found more convenient and expedient to employ special machines that have been designed expressly for the purpose.

The principle employed is to hold the valve in a collet on a spindle (Fig. 184 (A)) that is driven at a relatively slow speed, and by means of a suitable hand-feed mechanism to bring the face of the valve gradually into contact with the high-speed grinding wheel. The latter rotates to give a surface cutting speed of 5,000–6,000 ft. per minute, and such is the cutting action of the abrasive wheel it requires a matter of a few seconds only to reface a slightly worn valve.

In the modern valve-grinding machines, provision is made for grinding valves having face angles of 30°, 45°, and 90° and also to grind the butts of valve-stem ends and rocker-arm faces.

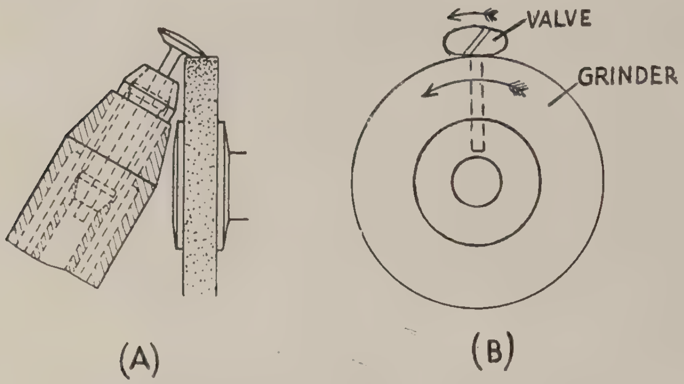


Fig. 184.—Showing Principle of the Valve-grinding Machine.

In regard to the directions of rotation of the valve head and grinding wheel, these should be as shown in Diagram (B), Fig. 184. It will be observed that when viewed from the grinding-wheel side both head and wheel *rotate in the same direction*, but at the point of contact of the two the linear directions are opposite.

A typical valve-refacing machine is shown in Fig. 185, the principal items being lettered.

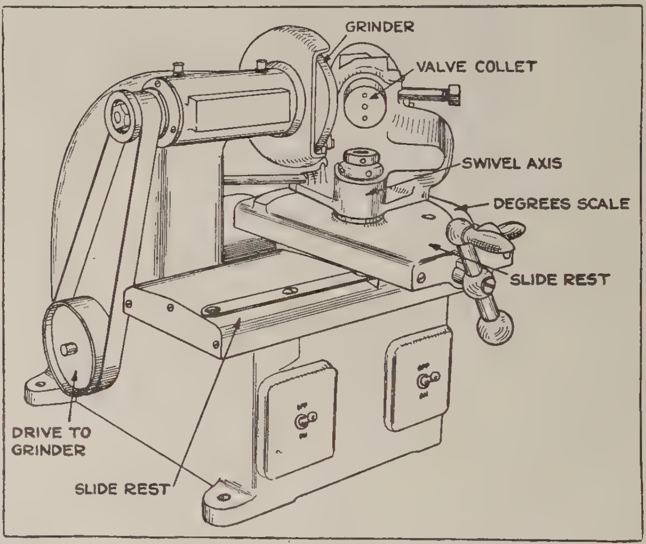
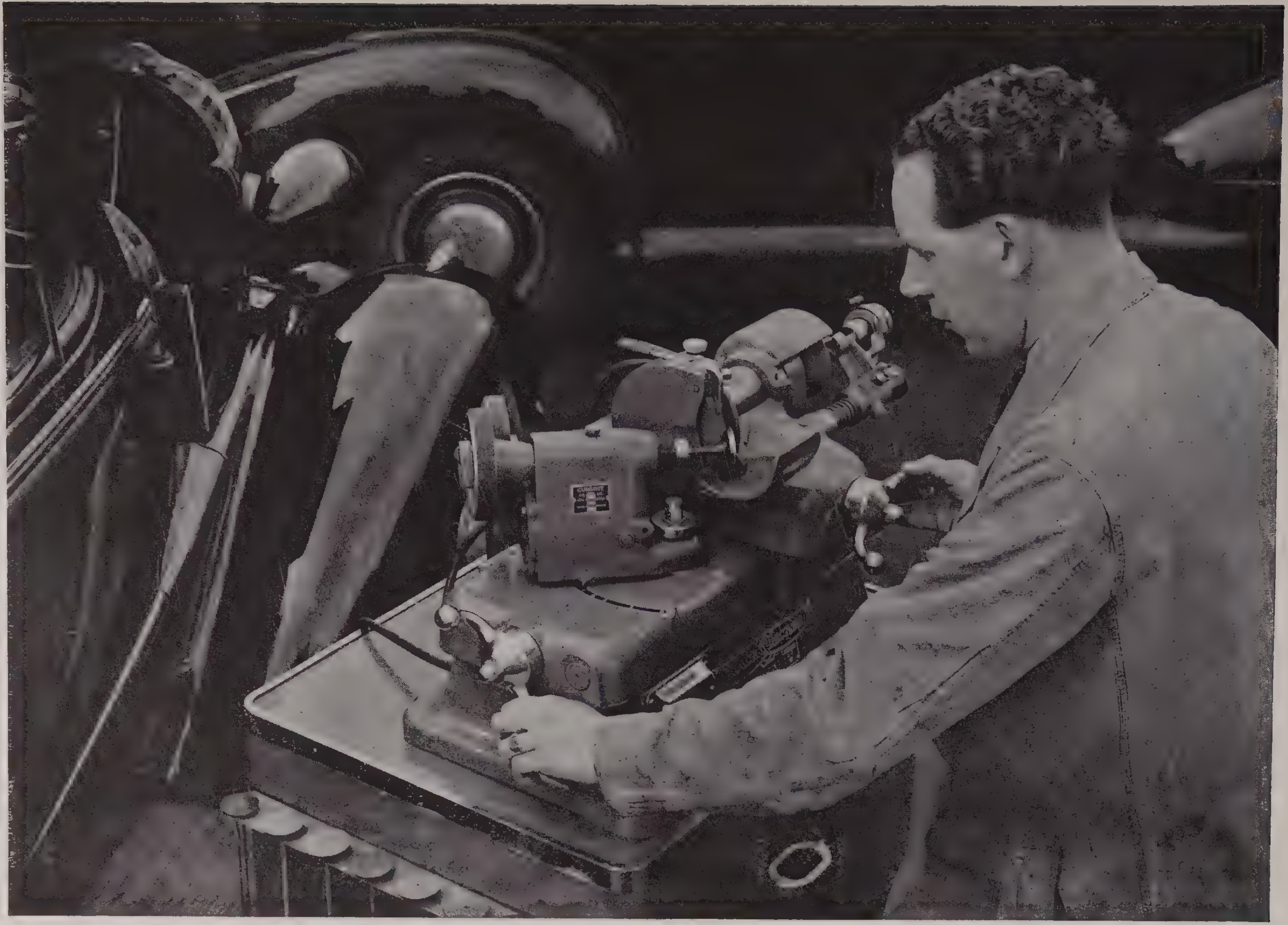


Fig. 185.—Electric Motor type of Valve-facing Machine.

The valve is held by its stem in a collet chuck, the latter being mounted in a bracket which can be rotated to the valve-seat angle marked on the scale shown. The valve-holding unit is mounted on a slide rest for the purpose of bringing the valve into contact with the grinding wheel shown; the wheel is belt-driven from a concealed motor. The same motor also



THE BLACK & DECKER " VALVE MASTER " VALVE-REFACING MACHINE IN OPERATION.

drives the valve collet and valve, by means of a reduction gearing, so that the valve rotates very slowly in relation to the speed of the grinding wheel.

This valve machine is made in several different models, with capacities for valves of $\frac{1}{4}$ in. to $\frac{1}{2}$ in. stem diameter.

A recent type of valve-refacing machine, known as the Master Refacer[1] is illustrated in Fig. 186. Its special features include provision for wet grinding in order to obtain fine finish; a double-ended collet for accurate centring of the worn valve stem; separate electric motors for the work table (operating the valve to be refaced) and the grinding wheel; adjustable angle of grinding; accurate finger-tip control of the grinding adjustments; self-aligning, spring-loaded, oil-impregnated bearings, and a work capacity up to $\frac{5}{8}$-in. valve stems.

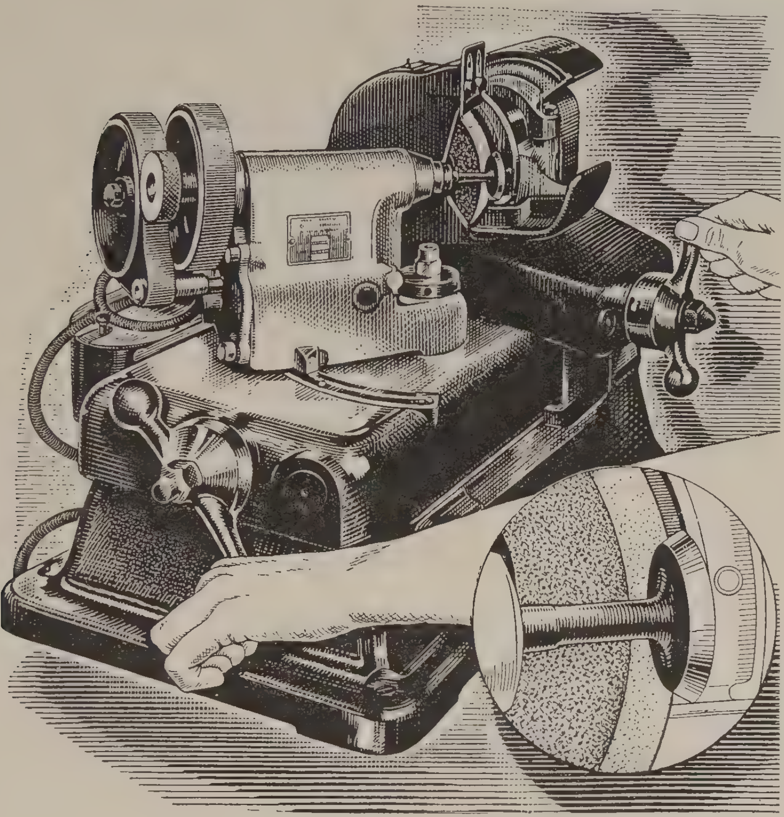


Fig. 186.—The Master Valve-refacing Machine.

The left-hand control handle moves the valve face towards or away from the grinder, whilst the right-hand one moves the grinding unit towards or away from the valve face.

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[1] Black & Decker, Ltd., Harmondsworth.

Fig. 187 illustrates one of the models of the Van Norman refacer and small components grinding machine, the various parts being described in the caption below. A part-sectional view of the same machine is shown in Fig. 188. This machine is a heavy-duty one, covering all angles from zero to 90°, but with pre-set angles of 30°, 45° and 90°, using a dowel-pin setting device. A valve-stem butt grinder complete with a rapid micrometer device for quick and easy setting of the valve stem is also provided. This same unit can also be used for facing the ends of tappets. Either wet or dry grinding operations can be performed; the wet method gives the better surface finish. Provision is made also for truing the grinding wheel with the diamond dressing tool supplied. Rocker arms can also be reground, using the device shown in Fig. 190.

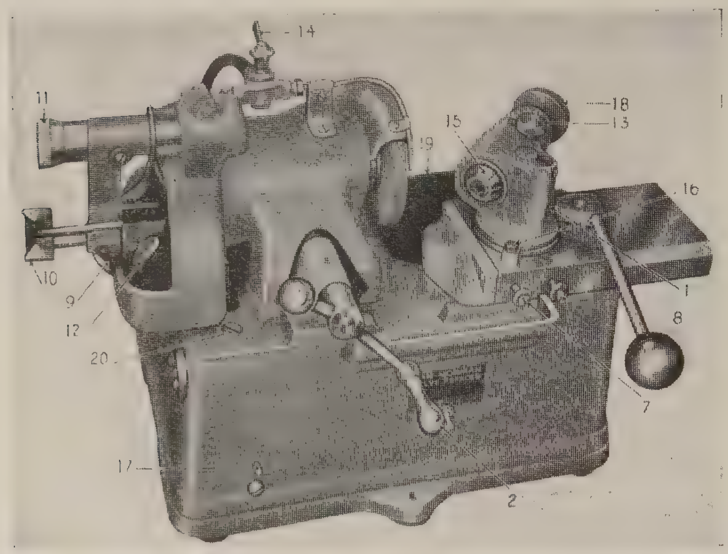

Fig. 187.—The Van Norman Valve Refacer and Grinder.

Key to Figs. 187 and 188: 1. Oil Level Plug. 2. Wheelhead Slide Handle. 3. Workhead Drum Pulley. 4. Workhead Drum Shaft Collar. 5. Workhead Drum Shaft. 6. Workhead Drum Shaft Oil Fitting. 7. Diamond Dresser Attach Screws. 8. Traverse Lever. 9. Vee-Block Valve Stop Lock-screw. 10. Vee-Block Valve Stop. 11. Micrometer. 12. Valve Lock. 13. Workhead Index Pin. 14. Petcock. 15. Valve Chuck. 16. Workhead Index Clamp. 17. Pump Oil Hole. 18. Workhead Chuck Knob. 19. Coolant Tank. 20. Workhead Drum Access Plug.

Butt Grinding of Valve Stems

The ends of valve stems can be ground square with the axes on the Van Norman machine illustrated in Figs. 187 and 188. In the case of the Ford valves, which have mushroom ends and split valve guides, it is necessary to obtain the correct tappet-stem clearance by the butt-grinding method, since there is no provision for valve-stem clearance adjustment on these engines. The method employed for both valve stems and tappet ends is as follows:

Butt grinding of valve-stem ends and tappets is done on the left-hand cup grinding wheel, using the special micrometer bracket (11) (Fig. 188) and the micrometer depth gauge (Fig. 189). This grinding operation should always be done wet in order to avoid inaccuracies due to thermal expansion of the valve if ground dry. Micrometer depth gauges to suit the mushroom-end Ford valve stems are supplied, the method of using this type of gauge being as follows:

Insert the entire gauge into the valve-guide bore in the cylinder block.

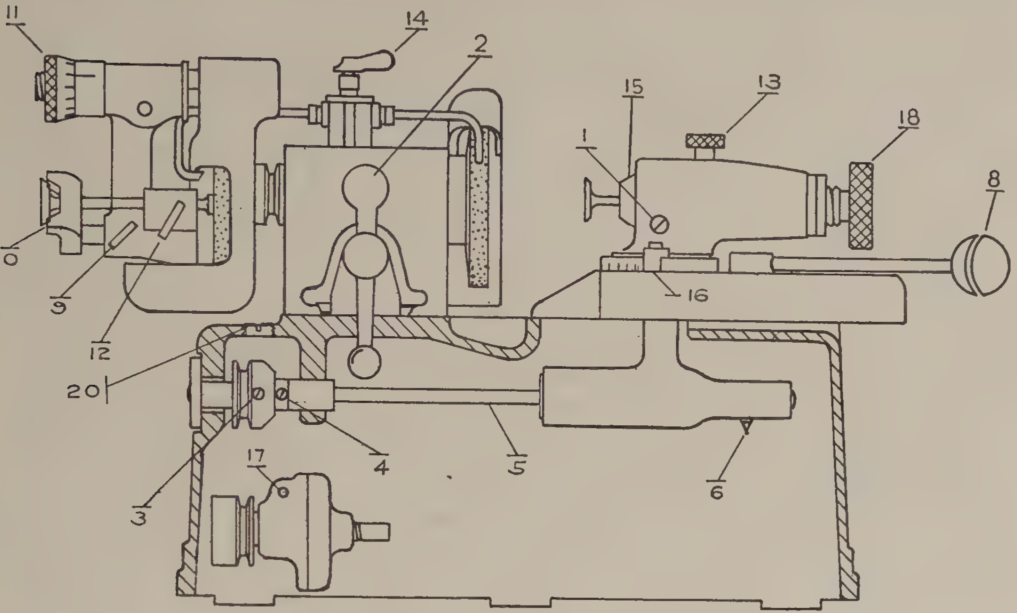

Fig. 188.—Part Sectional View of Machine shown in Fig. 187.

Push the gauge rod down against the tappet, with body in contact with the finished ground valve seat. (Motor should be rotated so that camshaft brings the tappet to its lowest point.)

With the gauge rod contacting the tappet, tighten the thumb nut. You now have a gauge which is set to the distance from the top of the finished ground seat to the top of the tappet. Valve clearance must be subtracted from this measurement.

Place the gauge in the butt-grinder bracket (10), after adjusting the micrometer bracket nut so that the two zero lines on this micrometer coincide. Securely lock the gauge (Fig. 189) in the butt grinder, using screw (12), with its rod touching the side of the abrasive wheel which has been trued.

Bring valve-stop bracket (10) against the face of the valve and lock it securely with screw (9). The measurement from the finished valve seat to the top of the tappet has now been transposed to the grinding fixture. As indicated above, the valve clearance must be subtracted from this distance.

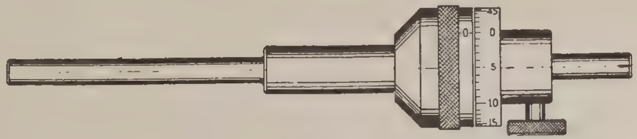

Fig. 189.—Micrometer Depth Gauge for use when grinding Valve-stem Ends (E. P. Barrus Ltd.).

The valve clearance is set with the bracket micrometer (11). This micrometer is graduated ·001 in. per mark, and is arranged so that the clearance is read directly. Thus, if a clearance of ·015 in. is desired, set the micrometer to ·015 in. by turning it in to number 15.

Regrinding Valve Rocker Arms

The worn operating faces on overhead-valve gear rocker arms can be trued up on the Van Norman valve-refacing machine shown in Figs. 187 and 188 by means of the attachment shown in Fig. 190. It will be observed that the side of the grinding wheel D is used for this purpose. The procedure is as follows: first true the side face of the grinding wheel with the diamond dressing tool, using a coarse traverse since the wheel thus dressed will cut much faster and with less heat than for a finer traverse. It is then necessary to select one of the special cones E or F (Fig. 190), namely one that will enter the hole in the central part of the rocker arm, i.e. the rocker shaft hole. The thumbscrew G is then tightened so that the cone can be held down firmly without the stud H rotating. After locking the rocker arm C securely in position, the thumbscrew G should be backed off so that the rocker arm is free to swivel.

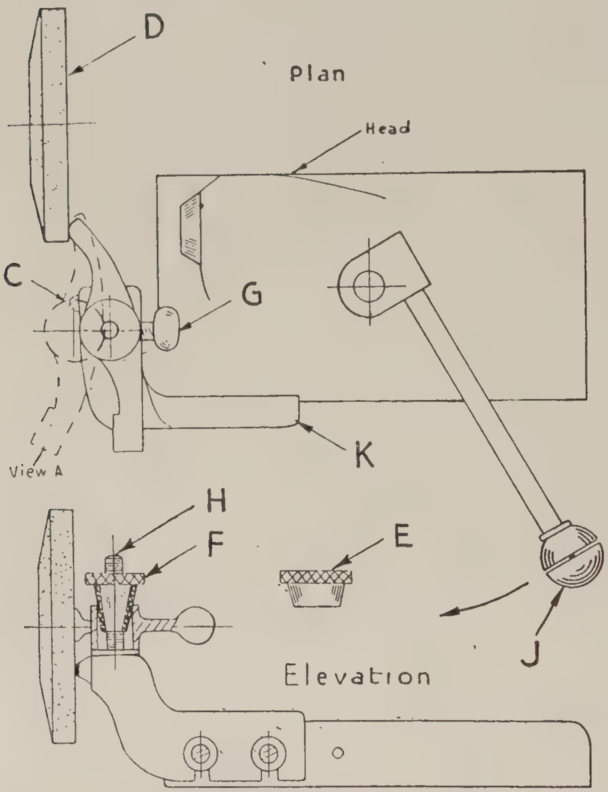

Fig. 190.—Rocker Grinding Attachment.

By means of the crank on the grinding-wheel head, the rocker arm is then brought into the position shown in the upper diagram of Fig. 190. The rocker arm is then pressed lightly against the side of the grinding wheel with the left hand, and the workhead slide is traversed backwards and forwards quickly by means of the knob J in the direction shown by the arrow. The radius on the rocker arm will then follow the side of the grinding wheel and all irregularities will be removed.

It is important to note that the casting K should always be held down against the slide when tightening down the attachment screws; this ensures that the attachment will be set up squarely.

Using Workhead for Stationary Grinding

It is possible to carry out plain grinding operations on the Van Norman machine shown in Fig. 187 by arranging for the workhead to remain stationary. This is done by disconnecting the power drive. Referring to Fig. 188, the plug (20) is first unscrewed in order to expose the setscrew (3) on the workhead-drive pulley inside the base. This setscrew should then be unscrewed, thus allowing the pulley to rotate but without driving the shaft.

Notes on Valve-refacing Machines

Before refacing a valve in a valve-grinding machine it is important to to ensure that the valve stem is perfectly clean and straight; otherwise the valve face that is reground will not be concentric or at right angles to the valve stem. Further, there should be no play in the workhead or grinding-head spindles. The work ways of the machine should always be kept clean and the driving belts properly tensioned. The grinding wheel must be dressed as soon as it shows signs of uneven wear or non-cylindrical action.

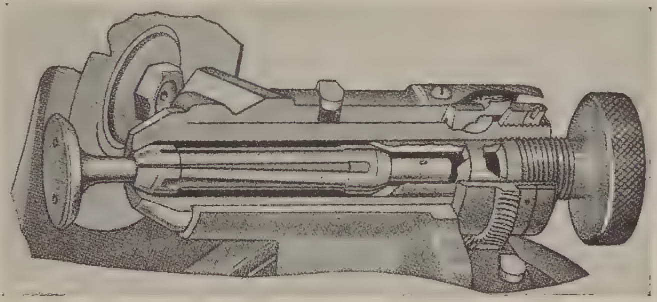

Fig. 191.—Showing Method of holding the Valve to be Refaced in Machine.

Valve-stem ends should always be ground wet.

Reclaiming Worn Valves

In many instances the faces of exhaust valves can be reconditioned and their useful life extended for a relatively long period by the process of welding nickel steel, a special alloy of nickel or chromium, or Stellite on to the valve faces.

When Brightray[1] (nickel-chromium alloy) or Stellite is used for building up the valve faces the deposit is considerably harder than the original valve steel; indeed, the same method is now frequently employed for facing new valves to give them from 3 to 5 times the usual life before regrinding becomes necessary.

The valve to be built up should be held in a jig which holds the valve with its stem vertical, the valve head being at the bottom. The holder for the valve head should be arranged to rotate about a vertical axis.

[1] Henry Wiggin & Co., Ltd., London.

Usually it is preferable to grind the worn valve face concave as shown in Fig. 192 and to deposit the alloy as shown by the shaded area (Fig. 193). The oxy-acetylene blow-pipe is used for fusing the alloy deposit on to the valve face, notes on the procedure being as follows:[1]

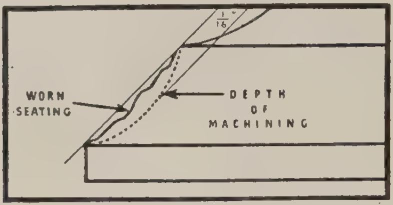

Fig. 192.—Method of Reclaiming Worn Valves.

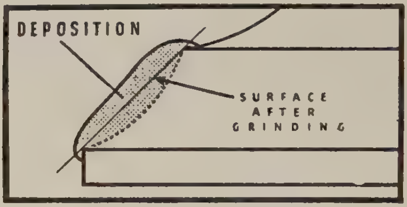

Fig. 193.—Deposition of Hard Metal on Valve Face.

A deposit from a 3½ per cent. nickel rod is less hard and is less resistant to heat and corrosion than rods in the other two categories previously mentioned. It should, therefore, be used only where wear is excessive. In such instances, it provides a backing over which a final run of either of the other two rods can be put down.

Flame condition is important. For depositing 3½ per cent. nickel rod the flame should be neutral, but to guard against it oxidising a slight " haze " of acetylene beyond the inner cone is permissible. After the head has been generally heated up for a few moments, deposition can commence, using the ordinary full-fusion technique. During deposition no more heat should be put into the valve head than is necessary. Over-heating makes it difficult to control the weld metal and causes oxidation and blowholes. A badly worn valve should be built up in two runs, the surface of the first run being ground clean before applying the second run.

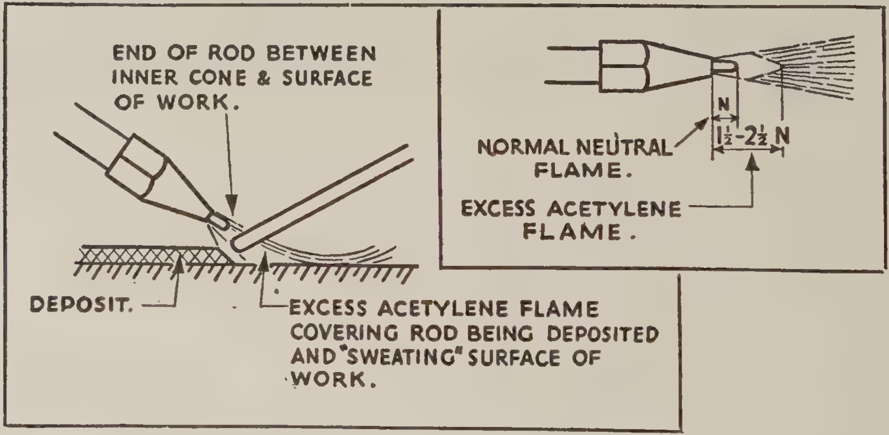
END OF ROD BETWEEN INNER CONE & SURFACE OF WORK.
DEPOSIT.
EXCESS ACETYLENE FLAME COVERING ROD BEING DEPOSITED AND "SWEATING" SURFACE OF WORK.
N
1½-2½ N
NORMAL NEUTRAL FLAME.
EXCESS ACETYLENE FLAME.

Fig. 194.—The Blow-pipe Flame and Angle.

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[1] Production and Engineering Bulletin.

After deposition the head should be reheated to an even temperature and allowed to cool as slowly as possible.

Rods of Brightray or Stellite are deposited by what is known as the "surface-fusion" technique. A similar-size tip to that required for $3\frac{1}{2}$ per cent. nickel rods should be used, and the flame adjusted to neutral with a cone of normal length. A carbonising flame is then obtained by turning down the oxygen valve on the blow-pipe until the white cone of excess acetylene is $1\frac{1}{2}$–$2\frac{1}{2}$ times the length of the inner cone. Fig. 194 illustrates this, and also indicates the correct angle of the blow-pipe and rod.

The valve head should be given a preliminary preheat with the blow-pipe, and the flame then applied to the seat with the inner cone just above the surface of the steel; at the same time the rod should be held in the flame to warm it up. In a few moments the surface of the steel will begin to "sweat" and form a film of carbonaceous steel with which the materials will readily combine. The end of the rod should then be brought under the flame and the small bead melted off will spread over the surface of the steel and "tin it." In this way deposition is continued round the valve head, and if one run does not give a thick enough deposit it can be repeated. A light deposit should be put down by the first run in order to avoid dilution of the deposit by the base metal, and it is important that the latter is not brought to the fully molten state. When deposition is completed the flame should be withdrawn slowly. To make grinding easier the deposit can be remelted and the valve slowly rotated by hand. This will give a very smooth surface, free from ripples. The valve should then be cooled very slowly by covering it with dry sand or lime.

When cold, the valve can be ground in the usual way, but a deposit made by a rod in the third category requires a special type of grinding wheel running at a rather higher speed. Manufacturers of grinding wheels make appropriate recommendations. Over-heating during grinding is likely to lead to cracking of the deposit. Besides valve heads and the ends of valve stems many other components, such as rockers, tappets, and clutch fingers, can be reclaimed in this way.

Reconditioning Valve Seatings

Valve seatings after long service become pocketed and, as previously mentioned, obstruct the free flow of the gases. The result is a loss of power and increased fuel consumption. When servicing engines, therefore, the valve seatings should be carefully examined for pockets (see Fig. 195), and if found necessary the seatings should be reconditioned. If badly worn the seating should be built up by welding a suitable iron or alloy, as described in another section. Otherwise, there are two alternative machining methods that can be employed, namely (1) the use of conical toothed cutters, resembling milling cutters, and (2) by grinding the seatings with conical abrasive stones.

Notes on Valve Reseating

In connection with the use of valve-reseating tools it is important not only to reface the inclined or conical seating, but also to remove the surplus material from the edges of the seating, otherwise the valves become pocketed, and the inflowing or outflowing gases are obstructed with serious effects upon the efficiency of the engine.

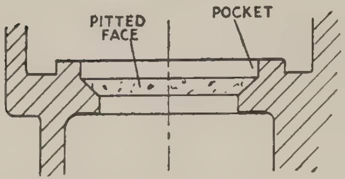


Fig. 195.—Defective Valve Seating.

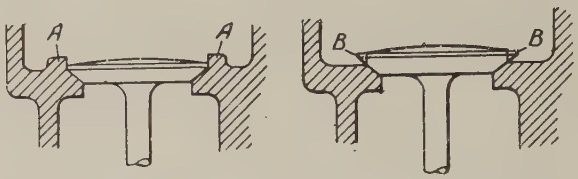


Fig. 196.—Illustrating Defects in Valves and Valve Seatings.

Sometimes the valves become both pitted and pocketed, as shown in Fig. 196 at A, after much use; the surplus material, shown at A, should be removed when reseating.

Occasionally when a valve is refaced, the face becomes too wide and offers obstruction to the gases. Here, again, the surplus material at B (Fig 196). must be turned off, so as to give an unobstructed flow to the gases.

The valve-reseating tool should be guided, relatively to the valve guide, by means of a suitable shaft or arbor fitting in the valve guide, and just able to rotate freely but without side play. If no such guide is employed, there is a big risk of the new seating not being true with the valve guide, and the valve will not bed properly, but will touch on one side and tilt slightly. All good makes of valve-seating tool are provided with adjustable or interchangeable guides.

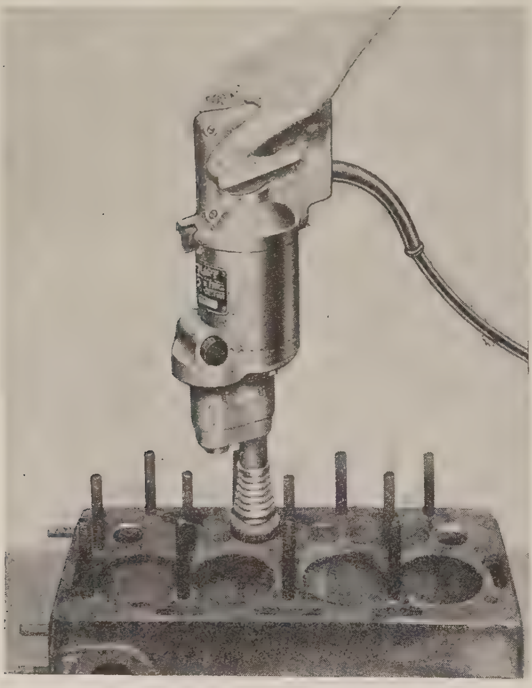


Fig. 197.—The Wolf Portable Electric Machine, used for Valve-seat truing.

Valve-seating Cutters

Special high-speed tool-steel cutters are available with different conical angles for cutting new valve seatings in cylinder blocks or heads. These tools are used in hand-operated holders as a rule, since the cutting speed required is slow and an electric portable tool would give much too high a speed. The cutters are made with certain standard bores and angles, the latter including angles of 30°, 45°, 60°, and 75°. Usually the cutters are supplied with shank members, having at one end pilots or guides to fit standard valve-guide holes and at the other end a driving portion for the operating handle or wheel.

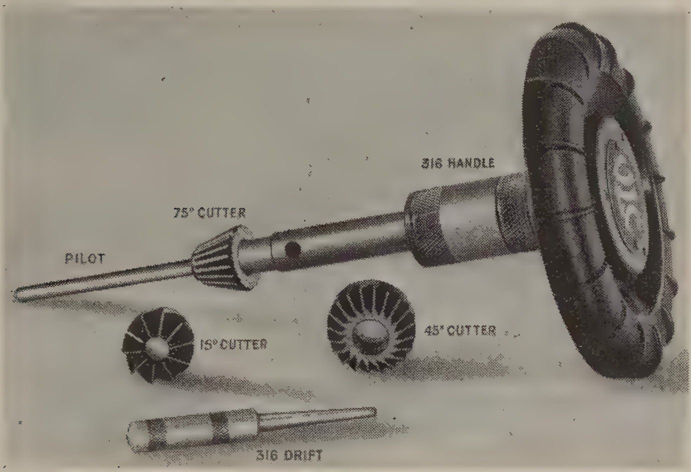


Fig. 198.—The Churchill Valve-seat Cutter Set.

Fig. 198 illustrates the Churchill valve-seat cutter set. The upper large illustration shows the complete tool, comprising the cutter, pilot, shank, and operating wheel. The latter is made of plastic and is ribbed for the purpose of increasing the grip. The relatively large diameter of the operating wheel gives a smooth and easy cutting action; moreover, it allows even pressure to be exerted all the time. This is a distinct advantage over the T-handled type of cutter holder.

The cutters have staggered teeth in order to avoid chattering when cutting. The cutter and pilot member is a tapered fit in the shank and is driven out when it is necessary to change the cutter by means of the tapered drift shown below in Fig. 198. Three different sizes of cutter, namely 15°, 45°, and 75°, are illustrated, but other cutter angles are used to suit different cylinders and seatings.

The Buma valve-seating tool shown in Fig. 199 enables seatings to be machined quickly and accurately for taking inserts. It employs flat cutters, the cutting radii of which can be set with the use of a stand and micrometer unit supplied. The tool has an automatic feed, regulated by

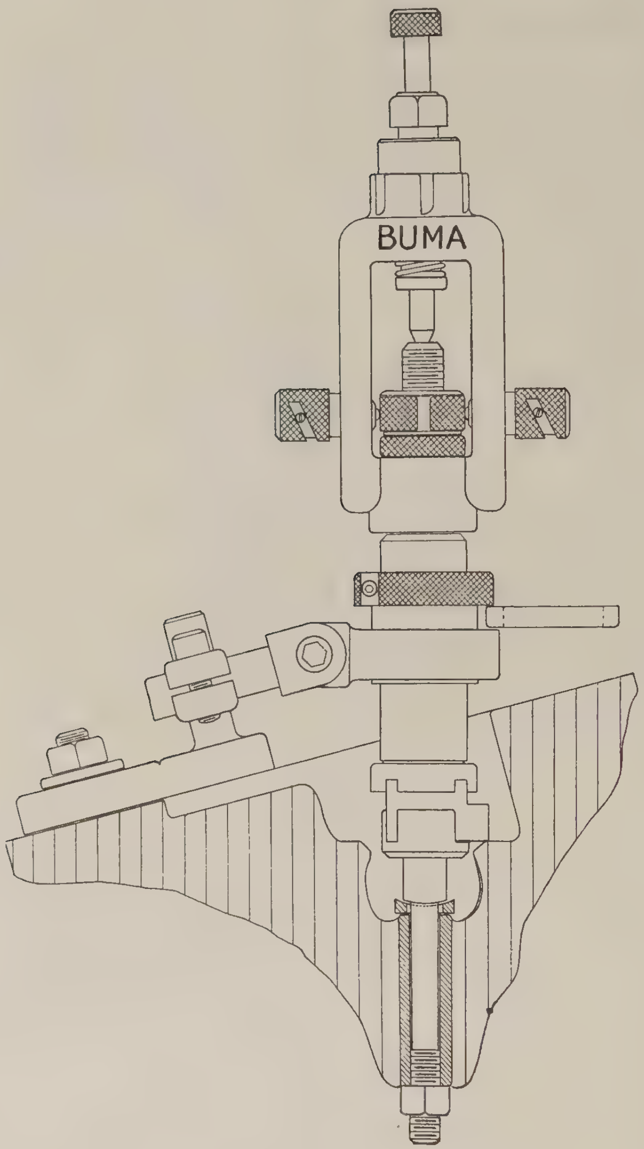


Fig. 199.—The Buma Valve-seating Tool.

a slight movement of the knurled sleeves, and can be varied as required. The pilot stems fitting the full length of the valve guide, and supported overhead by a universal steady held to the cylinder block or head by stud or bolt, can readily be set, irrespective of the valve stem and seat angle (Fig. 199). Alignment can also be checked by means of a flanged setting bush which also acts as a gauge for the depth of the counterbore to take the valve-seating insert. A range of cutters and pilot stems of different sizes is supplied, so that the tool can be used for a wide range of makes and sizes of engines for valve-seat insert purposes.

Principle of Valve-seat Truing

When a badly pocketed seating is to be reconditioned it will be seen that when the surplus metal at DKA (Fig. 200 (A)) is removed, this leaves a much wider seating, DB, of the correct valve angle. For the greatest power and efficiency it is necessary to reduce the width of this seating to a little more only than the valve-face width. The usual method of doing this reduction is to employ a 15° cutter to remove part of the seating ADE at the top, and a 75° cutter to remove another part of the seating BCF at the bottom, as shown at (B) in Fig. 200. The final width of the seating then becomes AB.

After the seating has been machined in this manner the valve is ground on to it, using an abrasive powder and vaseline or oil.

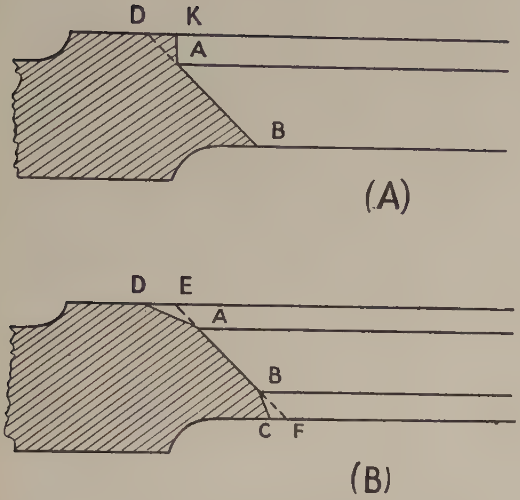


Fig. 200.—Valve-seating Method.

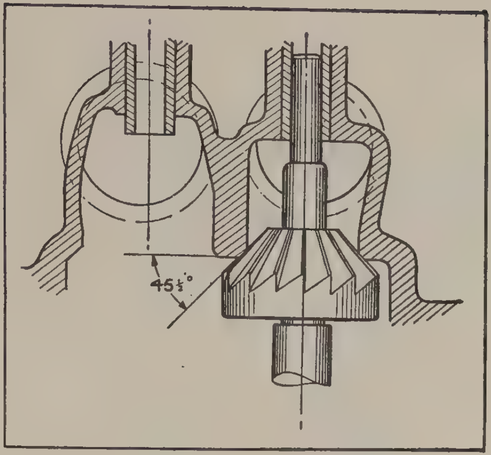


Fig. 201.—Using 45° Cutter for Truing Valve Seatings.

Servicing Vanguard Engine Valve Seatings

The overhead-valve seating reconditioning procedure recommended by the manufacturers of the Standard Vanguard engine is illustrated in Figs. 201 and 202. The method in question is employed when the valve-seatings are pocketed or badly pitted. The seating should be machined with a cutter having an included angle of 89° ($44\frac{1}{2}$° to axis), utilising a pilot of $\frac{5}{16}$ in. diameter, if the valve seating is not pocketed to any appreciable extent.

When serious pocketing does occur, however, it is recommended that a 15° seating cutter should first be employed, as shown in Fig. 202. Afterwards a $44\frac{1}{2}$° cutter should be used. When the necessity for recutting a valve seating arises it is important that the valve guides are concentric with their valve seatings. If the valve guide shows any appreciable signs of wear it should be removed and a new one fitted.

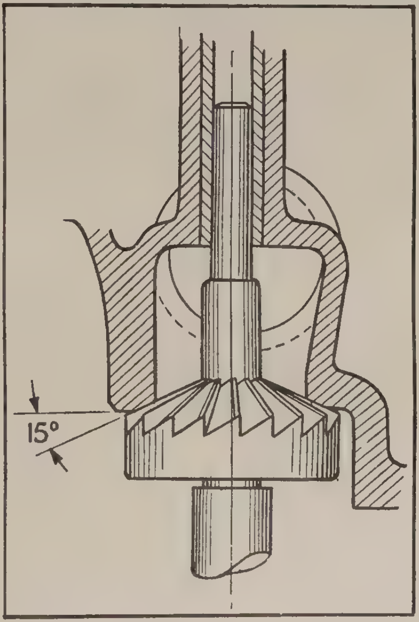


Fig. 202.—The 15° Cutter used for Pocketed Seatings.

It should be mentioned that the valve-face angles are 45° for both inlet and exhaust valves in the Vanguard engine. The inlet and exhaust valve heads are of $1\frac{1}{2}$ in. and $1\frac{9}{32}$ in. diameter respectively, and the widths of both valve faces are $\frac{1}{16}$ in.

The included angle of the valve seating is 89°, or $44\frac{1}{2}$° seating angle.

Valve-seating Grinding Methods

When seating cutters are employed the surface left after machining requires finishing by the abrasive paste grinding method, but when the seating is machined by means of conical grinding stones the surface is of a finer texture.

The conical stones employed are of the general shape and angles depicted in Fig. 203; in some cases the stones are grooved down their cutting faces; the grooving tends to *prevent glazing of the stone*, an effect that reduces the cutting efficiency and may cause *scoring of the seating*.

The conical stone is rotated at a relatively high speed in order to give the correct cutting speed by means of an air- or electric-motor drive. Thus with the usual cutting speeds for abrasive stones of 4,500–5,500 ft. per minute the speed of a stone of 1½ in. diameter would be between 12,000 and 16,000 r.p.m.

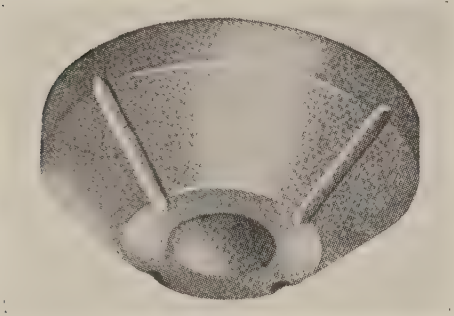


Fig. 203.—Grooved Conical Valve-seating Abrasive Stone.

If a plain conical abrasive stone were used continuously on a cast-iron seating it would tend to score the latter in just the same way as in valve regrinding, using an abrasive paste, continuous rotation of the valve will cause ridging or grooving. It is necessary, therefore, *to lift the stone from off the metal seating* from time to time during the grinding process. In this connection it may be mentioned that certain valve-seating equipment provide automatic means for preventing any grooving by lifting the stone at regular intervals.

When grinding valve seatings it is necessary to have a stone mounting with *an accurate pilot or guide* at the one end and a driving spindle at the other. Special designs of pilot ends are available with each make of valve-seating tool.

It is important to remember that abrasive stones rotated at their proper speeds of rotation will cut the metal fairly quickly, so that *care must be exercised to prevent too much metal being removed from the seating.*

Glazing of the grinding stone, due to continuous rotation when the abrasive dust and metal particles become embedded in the surface of the stone, should always be avoided. The presence of dirt or grease on the stone or seating will also cause clogging of the stone with loss of cutting efficiency.

The Churchill Pneumatic Valve Tool

A neat and efficient valve-seating tool operated by a tiny compressed-air motor and made by Messrs. V. L. Churchill & Co., Ltd., London, is illustrated in action in Fig. 204. The device employs a high-speed reciprocating action on the abrasive head. Light pressure on the head opens the air-inlet valve, and when the tool is lifted from the valve head the air supply is shut off. The speed of grinding is variable up to 2,000 strokes per minute. The air consumption is quite low, namely 2 cu. ft. of free air per minute. The method employed, namely by using the valve itself with an abrasive compound, is for reconditioning pitted seatings and valve faces, at the same time giving a very smooth and accurate finish to the bedding faces. The tool itself is very light, weighing only 22 ozs.

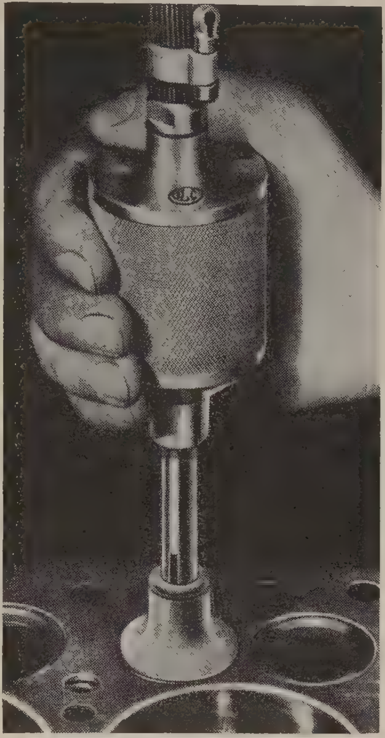


Fig. 204.—A Pneumatic Valve-seating Tool.

The Vibro-Centric Valve-seating Method

It has previously been mentioned that to obtain the best results when truing up valve seatings it is necessary to lift the abrasive stone from the seating from time to time. In the Vibro-Centric equipment the driving spindle of the stone, which is operated by an electric motor, is given a positive vibrating action, whereby the stone is lifted clear of the valve seating once every revolution of the stone. This clears the seating and also the stone of cutting abrasive and metal particles by centrifugal action, so that the stone always cuts cleanly and efficiently without any risk of glazing. The grinding cone is operated by a portable electric tool at about 12,000 r.p.m., and it cuts the whole width of the valve seatings at once. The grinding process is done "dry," and only the minimum of metal is removed from the seating if desired, but when an appreciable amount of metal is to be ground off the action can be made a rapid one.

The complete equipment, shown in Fig. 205, consists of the portable motor unit—also shown in Fig. 207—the various stones and pilots or guides to suit the valve-guide holes, and the stone dressing stand.

Provision is made for quickly changing the grinding cones on their spindles or sleeves. The stone dressing stand, shown in Fig. 208, enables the conical stones to be dressed, or trued, to any desired angle from zero to 90°. A diamond-pointed tool with an adjustable feeding arm is employed in conjunction with a micrometer vertical feed for truing the stones. Both vertical and horizontal cutting can be done on this stand. There is also an angle indicator which can be set to any given cutting angle. The spindle that holds the stones is grooved to take ball-bearing stone sleeves.

There is also a flexible shaft attachment for the Vibro-Centric machine to enable the grinding cone to be used in awkward positions on engines. The self-centring pilot used has two accurately machined tapers, one at the top, which fits into the top of the valve guide, and one at the bottom, on which a split sleeve expands into the lower end of the valve guide. These expanding features provide compensation for worn guides.

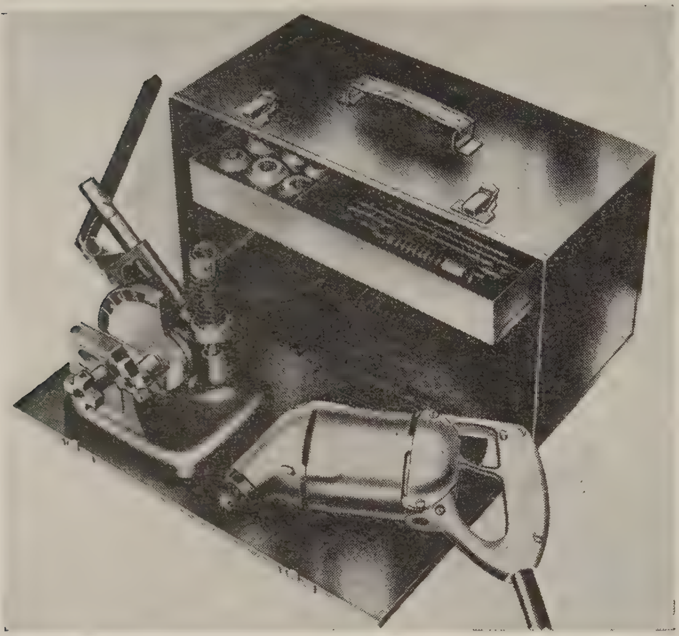


Fig. 205.—The Vibro-centric Valve-seating Equipment (Black Decker Ltd.).

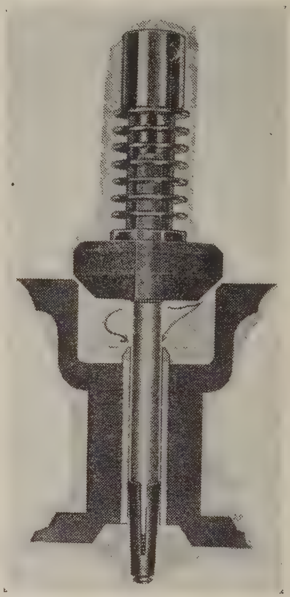


Fig. 206.—The Conical Stone and Pilot Guide Unit.

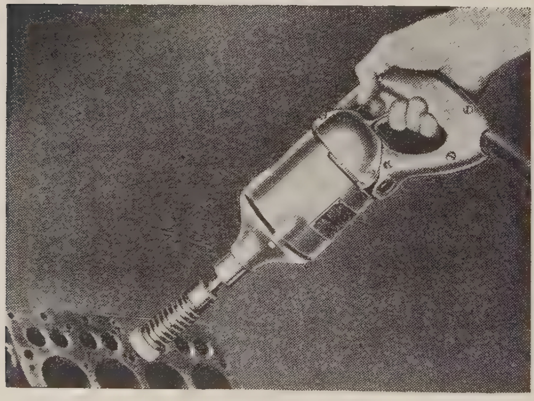


Fig. 207.—The Vibro-Centric Tool in Operation.

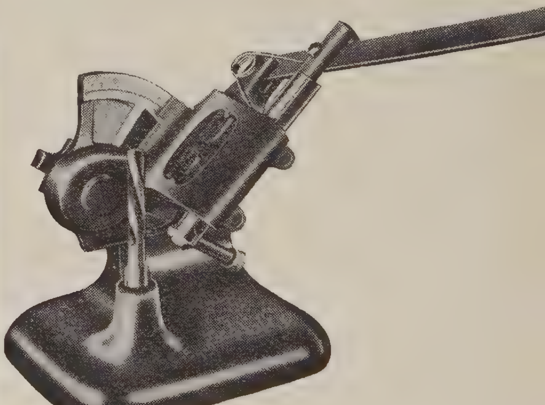


Fig. 208.—The Stone Truing Stand.

The Hall Eccentric Valve Reseater

The principle of the method employed in the Hall[1] valve-seating grinder is that of having only one point of the grinding wheel in contact with the valve seating at one time. The grinding wheel, which is of small dimensions, revolves at a high speed, and by an eccentric slow-speed movement of its spindle it covers the whole seating. It is claimed that with the grinding wheel revolving at high speed and making full contact with the seating, the accuracy of the finished seating is affected by the following three conditions, namely: (1) the striking of a hard spot which might cause the grinding cone to dig in or gouge the seat at a point opposite to the hard spot; (2) the loading and glazing of the wheel due to the inability to disperse its cuttings, so that grooves or ridges are produced around the valve seating; (3) the rapid wear of the grinding wheel. The manner in which the eccentric valve-seating grinding method obviates these possible disadvantages is illustrated in Fig. 209, which gives a cross-sectional view looking down at the grinder on the valve seating A. The pilot used for ensuring final concentricity of the ground seating with the axis of the valve guide is depicted at B. The grinding wheel shown at C is rotated by its electric motor drive at a very high speed, namely 10,000 r.p.m., by means of the driving unit or high-speed shaft D. This shaft revolves on ball bearings around the inner, or eccentric, shaft E. It should be noted that the pilot hole in the shaft E is located off centre. This method of location produces the eccentric action of the grinder. The inner, or eccentric, shaft E is arranged to revolve at 20 r.p.m. about the axis of the true seating.

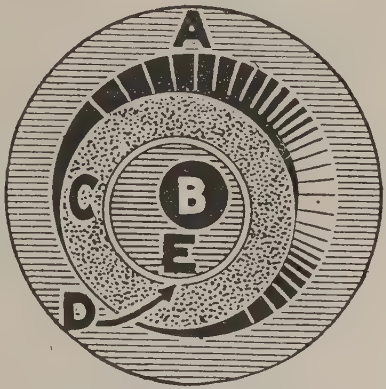


Fig. 209.—Showing Principle of the Hall Valve-seating Grinder.

The complete equipment (Fig. 210) includes an electric motor unit mounted on a stand that can readily be brought over any valve seating of the cylinder block. The drive to the grinding-wheel shaft is by gearing, the shaft speed being much higher than the motor armature speed in order to obtain the correct abrasive-wheel cutting speed. A micrometer feed is provided for applying the grinding cut. The machine is fitted with a calibrated balancing handle, and equipment is provided for the precision dressing of the stone at any angle.

A special design of expanding valve-guide pilot is supplied. This consists of a solid tapered type of spindle with an expanding, hardened, and ground collet capable of handling valve-guide holes from ·002 in. under size to ·008 in. oversize. The spindle has a gradual or " slow " taper to give a greater bearing in the valve guide. The pilot is small

[1] Messrs. Morris & Ingram, Ltd., London, E.C.2.

enough at the top of its taper to enter a counterbored guide and make its seating in the guide hole proper. The slow taper A (Fig. 211) locates the pilot centrally in the top of the valve guide. At the point B is the expanding collet which centres the pilot in the bottom of the valve-guide hole. An end view of this collet is shown at C; the method of external and internal grinding with the slotted portions in three places allows the collet to expand evenly when forced up on the lower pilot taper by the turning of the expansion nut shown at D. It is possible to remove and insert the pilot unit to within very close limits.

Various models of Hall valve-reseating equipment to suit a wide range of cylinder sizes from small car engines to large Diesel ones are available.

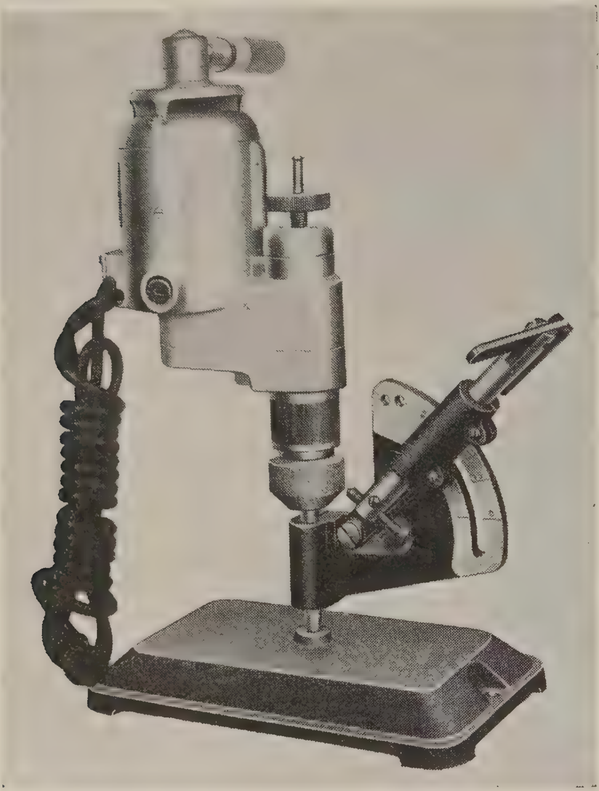


Fig. 210.—The Hall Valve-seating Equipment.

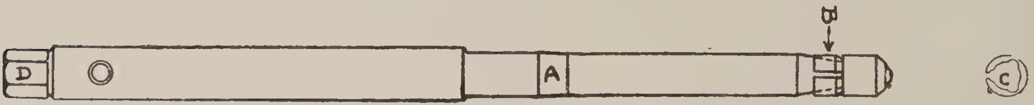


Fig. 211.—The Hall Expanding Valve-guide Pilot.

Grinding Stellited Seatings

When it is necessary to grind valve seatings that have been coated with extremely hard long-wearing materials such as Stellite or Brightray, it will be found that the ordinary abrasive stones that are employed for cast-iron and alloy-iron valve seatings will not touch these hard materials. It therefore becomes necessary to employ special abrasive stones such as Carborundum Green Grit or diamond dust impregnated stones. The suppliers of valve-reseating equipment will provide these special stones, or they can be obtained from the Carborundum Co., Ltd., Trafford Park, Manchester

It may also be mentioned that special grades of stones are now available for finish grinding and also rough grinding cast-iron valve seatings.

Building Up Worn Valve Seatings

Cracked or badly worn valve seatings in cast-iron cylinders or heads are often repaired by the oxy-acetylene welding process, in which the weld metal (usually an alloy iron) is used to build up the regions of the seating around which wear has occurred. It is necessary to preheat the cylinders (or heads) before welding, and to anneal them afterwards in order to avoid thermal stresses which might cause cracks in the metal. The actual welding operation must be performed by a specialist, and in this connection firms having a long and varied experience with this kind of work will undertake valve-seating welding repairs and reconditioning.

In some instances it is necessary to weld a complete disc of metal on to the worn valve seating and the cylinder metal around so that the metal melted becomes integral with that of the cylinder (or head). The welded seating is then machined by cutters and conical grinders truly concentric with the valve guide.

In cases where the new valve seatings have to withstand long periods of use with the minimum of maintenance attention they may be built up by the oxy-acetylene welding method, using hard seating alloys such as 3½ per cent. nickel steel, Brightray, or Stellite. The technique employed is somewhat similar to that described in the case of valve faces, but it is necessary to preheat the cylinder block or head in order to avoid any risk of distortion due to the application of local welding heat. When the hard facing alloys, e.g. Brightray or Stellite, are used the deposit is too hard for high-speed steel cutters to machine, so that the seatings require truing to form using special grades of conical grinding stones supplied by firms such as the Carborundum Co., Ltd. or the Norton Grinding Wheel Co., Ltd., for this purpose. The grinder is mounted on an arbor having an extension, or pilot, which enters the valve guide and thus ensures that the new seating is truly concentric with the valve-guide axis, as explained previously.

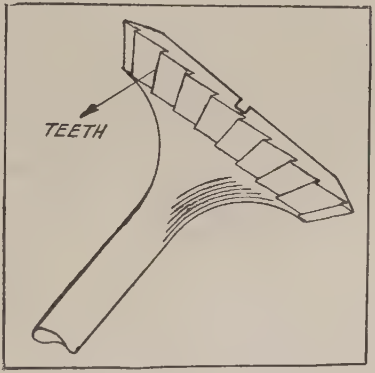


Fig. 212.—Valve-seating Cutter.

A Seating Truing Tool

A useful device for truing the valve seating after having fitted new valve guides is illustrated in Fig. 212. It will usually be found that *the seating is not true with the valve-guide* hole and must therefore be trued to the latter.

For this purpose one can use a discarded valve and skim the seating up in the lathe true and with as large a face as possible. Then with a three-square file cut teeth on the seating face as shown in the sketch. See that there is a good screw-driver slot in the head, or, if a tulip type of valve, see that the drilled holes inside the head are clear. Now harden the head, the method used depending on the kind of steel. To use the tool, treat as if you were grinding in the usual way, but relieving the pressure on the back stroke without, of course, using any grinding paste. A few turns with the screw-driver will soon square up the seat. Then the new valve can be ground in quickly with a little grinding paste.

Valve-seating Inserts

When the metal of the cast-iron cylinder block is used for the valve seating, owing to its relatively soft nature it requires truing at regular intervals. Each time this is done the seating loses some of its metal, so that "pocketing" and undue weakening of the metal are liable to occur.

Apart from the latter defects, the principal objection to the use of the cylinder iron itself for the valve seating is that of maintenance or servicing expense.

In order, therefore, to greatly prolong the lives of valve seatings and to increase considerably the periods of useful service before seat truing becomes necessary, it has become the practice in the case of many modern commercial and several car engines to employ a different metal for the valve seating; this metal is much harder than cylinder cast iron, not readily corrodible, and with a heat-expansion coefficient very nearly the same as for the cylinder metal.

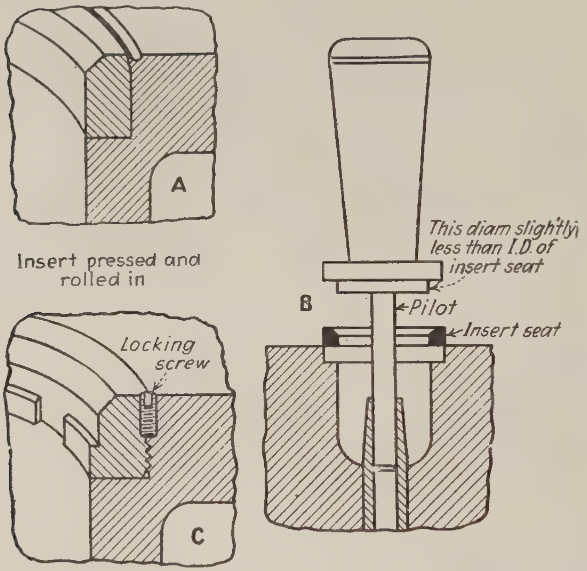

A
Insert pressed and rolled in
This diam slightly less than I.D. of insert seat
B
Pilot
Insert seat
Locking screw
C

Fig. 213.—Types of Valve-seating Inserts.

Hard aluminium-bronze seatings are used in aluminium-alloy cylinder heads of aeroplane engines. The high coefficient of expansion of this metal keeps it a tight fit in the cylinder head, whilst its heat conductivity is quite satisfactory. It cannot be used in cast-iron cylinders, however, as it tends to become loose when cold.

The materials used for inserted valve seatings are alloy cast irons, high-speed alloy steel, and steel rings having Stellited surfaces. Of the *alloy cast irons*, those containing nickel and chromium have been found suitable, the best results being obtained after the metal has been hardened and tempered.

An excellent alloy cast iron is that known as Ni-Resist; this contains copper and nickel in small quantities; it is, however, more suitable for aluminium-alloy cylinders or heads than for cast-iron ones, on account of its high expansion coefficient. High-speed steel rings of the nickel-chrome class are used for automobile valve seatings. These rings are usually made *an interference or press fit* in the cylinder-valve seating recess (as shown at A, in Fig. 213) and are driven into place or forced in by means of an hydraulic press.

The rings which are made an interference fit are *from* ·003 *to* ·005 *in. oversize* for smaller rings, the allowance increasing slightly for the larger sizes. *Too great* a press fit will result in scraping of the cylinder block so that the rings are apt to loosen later. In some cases the rings are threaded and screwed into the seatings, being afterwards " pinned " with a locking screw, as shown at C in Fig. 213.

A method of ensuring concentricity of fit, described in the *Machinist*, is shown at B (Fig. 213). In this case the seats are pressed into position, or tapped by hand with the device shown. The tool pilots in the valve guide, also on the inside diameter of the seating, and the inserting pressure is applied to the seat.

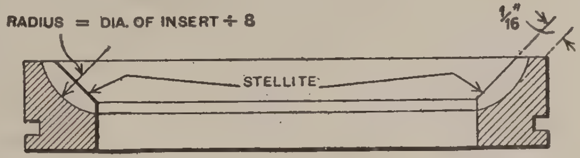


Fig. 214.—Stellited Valve-seating Insert.

Just before the insert touches the bottom of the seating, chips and dirt should be blown away with a compressed-air jet. In some cases this type of valve seating is inserted by the " freezing method," whereby the seating is first " shrunk " by immersing it in liquid air or " dry ice " and then quickly transferred into the cylinder-block seating location, where it expands and grips securely. Steel ring valve inserts having a surface layer of Stellite are used on A.E.C. oil engines, as well as on other makes.

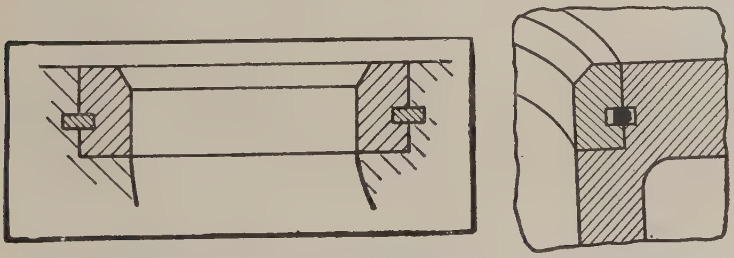


Fig. 215.—Method of fixing Valve-seating Rings by means of a Split Ring which engages with a Groove turned in Cylinder Valve Port.

Stellite is a synthetic material of an extremely hard nature, which is commonly employed for the cutting edges of tools used for machining purposes; it is much harder than the hardest alloy steel and therefore well suited to valve seatings.

Fig. 214 illustrates a typical seating of the Stellited-surface kind, the grooved portion being used in conjunction with an expanding ring resembling a small piston ring—to hold the seating in position; this expansion ring opens into a corresponding recess turned in the cylinder housing for the valve insert. Fig. 215 shows the expanding locking-ring method of securing the valve-seating insert.

Fig. 216 shows the Wellworthy method of ensuring a firm fit of the insert ring in the cylinder block. The valve-seating insert ring has two slots, arranged horizontally near the lower surface. The lower portions, below the slots, open out into recesses turned in the cylinder housing and thus lock the rings into position. A thin steel strip is inserted in each slot to obviate the possibility of vertical play.

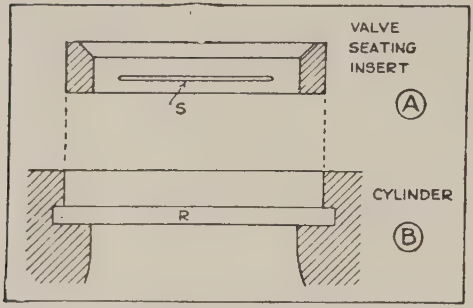


Fig. 216.—The Wellworthy Valve-seating Insert Method.

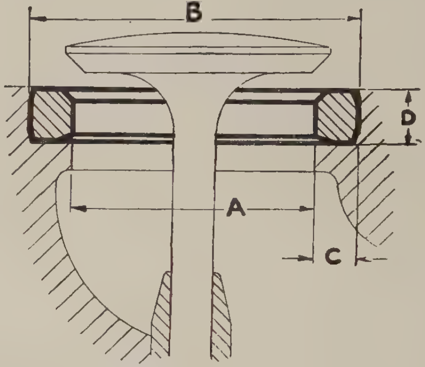


Fig. 217.—"Bricromium" Valve-seating Inserts.

The interference fit of the insert is sufficient only to ensure the complete contact which is essential for heat distribution, but the slotting (by giving a certain amount of flexibility) facilitates the fitting, and when the portion of the insert below the slot reaches its corresponding recess the release of pressure causes it to spring into the aperture. The material used is a centrifugal-cast alloy cast iron which has been found to be less affected by valve " bounding " than the normal hardened material.

Valve-seat inserts, made in a hard alloy cast iron, known as " Bricromium," made by the British Piston Ring Co., Ltd., Coventry, are available in a range of sizes for motor-vehicle engines. These inserts are specified, or ordered, by stating the four lettered dimensions shown in Fig. 217. Thus, A represents the inside diameter; B, the outside diameter; C, the radial thickness, and D, the width. The inside diameters are available in sizes from $\frac{7}{8}$ in. to $2\frac{1}{4}$ in., and the outside diameters from $1\frac{1}{8}$ in. to $2\frac{11}{16}$ in.

Valve-insert Tool

A special tool, known as the B and T Valve-insert Seat Fitting Tool, is available for the purpose of cutting the recessed hole for the valve seat to the exact size and also for inserting the valve seating afterwards.

The tool (Fig. 218) is clamped in position on the cylinder block and the cutter is fed down until it is just beginning to "bite" on the valve seating. The depth gauge is then set by means of the valve-insert ring. This automatically stops the feed when the cutter reaches the correct depth to suit the insert ring. The process of cutting the recess, by revolving the spindle whilst the feed is applied by the tommy-bar, is shown in Fig. 219. The recess, cut to the correct depth, is shown on the left in Fig. 220.

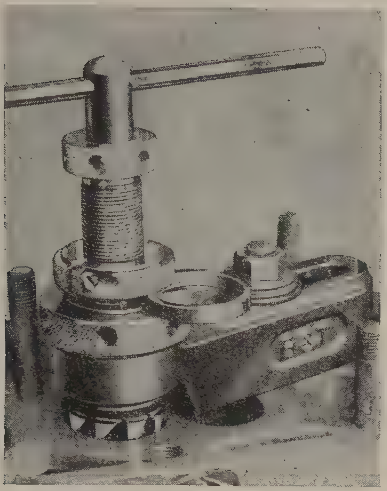


Fig. 218.—The Valve-insert Tool clamped in position on Cylinder Block, showing Depth Gauge set by Insert Ring.

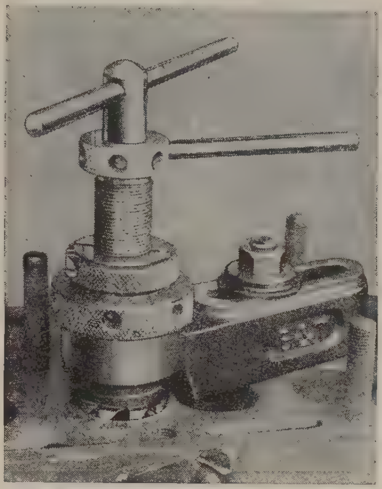


Fig. 219.—Showing Process of Cutting Recess by Revolving Spindle with top T-bar, whilst Feed is applied with Tommy-bar on Right.

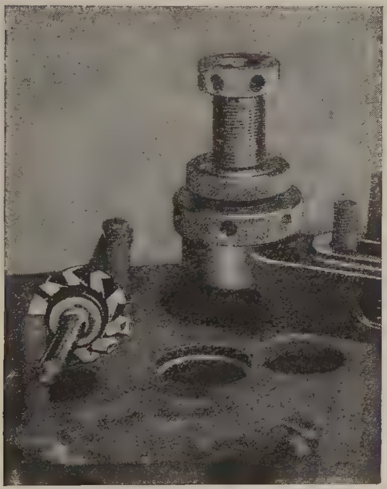


Fig. 220.—Showing Recess cut to Correct Depth and Size, ready for Valve-insert Ring Seat.

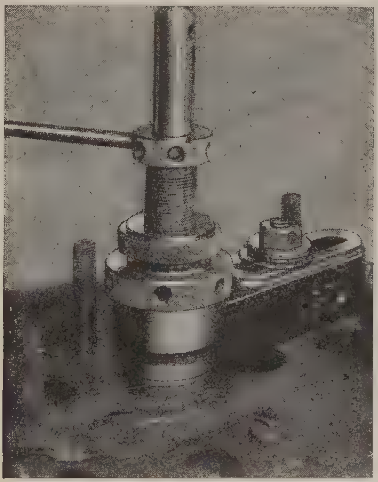


Fig. 221.—The Tool reassembled with Cutter removed and Press Piece inserted for forcing home the Insert Ring.

After this has been done, the tool is reassembled with the recessing cutter removed and the latter is replaced by a special *press piece* (Fig. 221). The chamfered side of the valve insert is placed over the recessed hole and the ring is then pressed home by means of the same feed-screw as before (Fig. 222).

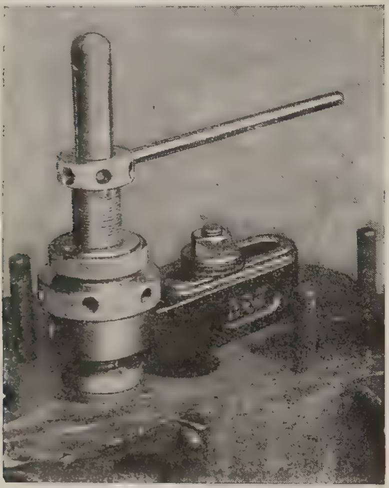


Fig. 222.—Showing Valve-insert Ring nearly pressed home.

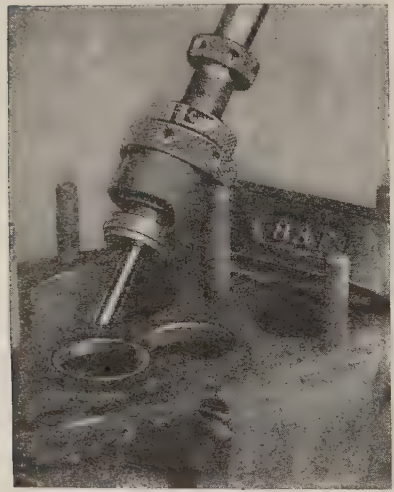


Fig. 223.—The Insert Ring right home with Tool removed and ready for cutting Angle Seat to suit Valve.

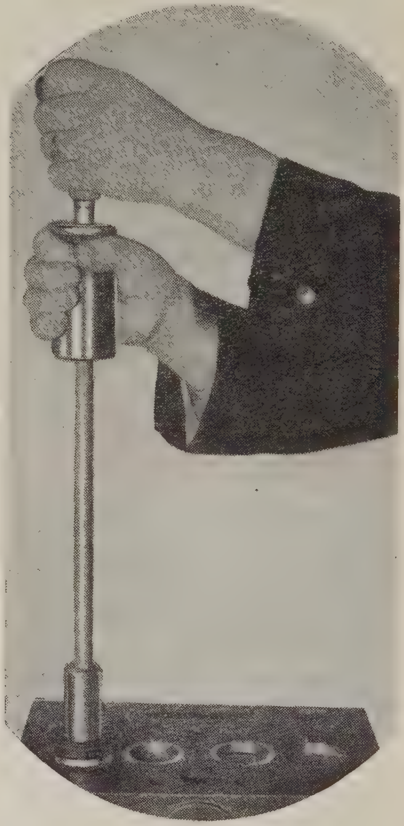


Fig. 224.—The Buma Tru-Blo Valve-seating Ring Insertion Tool.

This method is a quick one, and as it uses a pilot bar to locate the tool by means of the existing valve guide, it gives accurately centred holes.

The cutter employed has a relatively large number of cutting edges, which ensure truly cylindrical holes of smooth finish. This tool is used chiefly for fitting valve-seat inserts into engine cylinders having plain seatings. It is marketed by Messrs. Boneham & Turner, Ltd., Mansfield.

Another useful tool for inserting new valve-seating rings, known as the Buma Tru-Blo valve-seat driver, is shown in Fig. 224. It consists of a valve guide and disc—selected to suit the particular valve dimensions—and a long shank with wooden supporting handle above. A relatively heavy hammer of cylindrical shape can slide freely up and down the shank. The tool is used as follows: place the new valve seating in position over its hole in the cylinder block and lower the tool into valve guide. Then hold the wooden handle firmly in one hand and slide the hammer up and down with the other hand. A few blows will usually be sufficient to force the seating into position.

Testing for Bent Valve Stems

The valve stem is liable to become bent when removing the valve with certain types of valve-spring compressors and in particular with certain makeshift devices. Usually the amount of bending is small and cannot readily be detected by the eye.

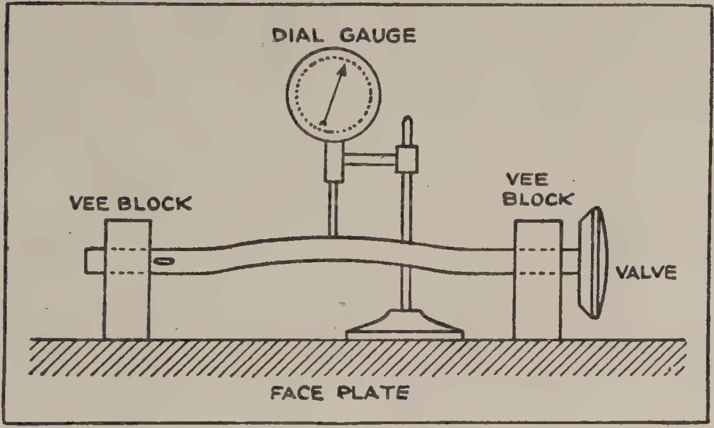


Fig. 225.—Testing for Bent Valve Stem.

One method of testing for a bent valve stem is to hold the stem at its valve-collar end, in a self-centring or collet chuck in the lathe (or a drilling machine, if suitable chuck is available). Upon rotating the chuck slowly, any want of alignment of the valve stem is readily observed; the dial indicator or the "chalk-mark" methods of finding the position of the bend can be used. An alternative method, illustrated in Fig. 225, is to use a pair of suitable V-blocks on a surface plate. The valve is turned round in the V-blocks and a dial indicator used to ascertain the position and amount of the bending.

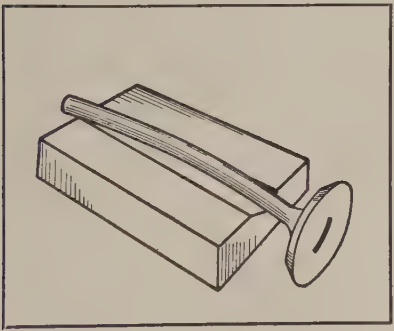


Fig. 226.

Straightening Bent Valves

Fig. 226 illustrates a simple method of straightening valve stems which have become bent. It consists of a block of metal having a V-groove planed along its length. The depth of the groove should be about one-half the diameter of the valve stem. The valve is placed in the groove as shown, and placed under a press—or even in a vice (if suitable soft clamps are used). If the valve stem is rotated occasionally in between the applications of the pressure it can quickly be straightened. In an emergency a block of hard wood, e.g. ash or oak, can be used for this purpose. Both skill and care are necessary to ensure accurate straightening of valve stems.

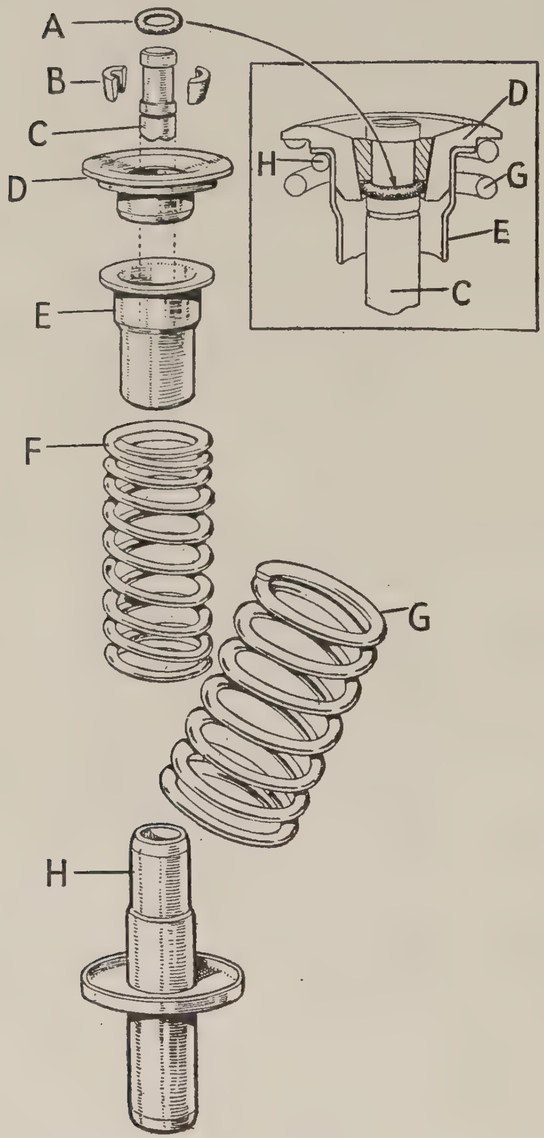


Fig. 227.—The M.G. 1¼-litre Engine Valve Components.

A—Synthetic Rubber Ring. B—Split Conical Cotters. C—Valve-stem End. E—Pressed Metal Shroud. D—Valve-stem Collar. F—Inner Valve Spring. G—Outer Valve Spring. H—Valve Guide (removed from Cylinder Head).

Preventing Oil Leakage along Valve Stems

The well-lubricated modern engine, more particularly the overhead-valve type, is now provided with means for preventing the liberal supply of oil to the overhead-valve gear from running down the valve stems, and thus tending to become gummy in the valve guides.

A typical example of the method employed is that of the M.G. 1¼-litre engine shown in Fig. 227. It will be observed from the upper right inset drawing that there is an oil-seal rubber ring below the split conical collar retainer; this ring prevents oil from running down the valve stem past the splits in the conical retainer.

There is also a pressed metal sleeve under the valve collar upon which the inner of the two valve springs used on this engine rests so as to maintain it in its correct position; this sleeve also serves as an oil excluder for the valve stem.

Prevention of Sticky or Burnt-out Valves

It is a well-known fact that with the use of leaded petrols a certain amount of trouble has been experienced with gummed-up valves and burnt valve faces. With such fuels there is apt to be deposited on the valves and valve seats a hard film, mainly lead oxide, resulting from decomposition of the lead tetra-ethyl, and it is this film that so greatly increases sticking, and also burning out, as compared with the use of an ordinary petrol hitherto supplied of low or medium octane rating not doped with lead.

It is generally well known that the addition of lubricating oil to petrol improves the operation of the engine, which is indicated also by the fact that the problem of sticky and burnt-out valves is reduced to a slight degree by this method. The real remedy, however, is the use of an *upper-cylinder lubricant* consisting of " dag " colloidal graphite dispersed in lubricating oil, available from the usual oil suppliers, which alters the whole position.

The graphite itself is a valuable lubricant, all the more so because under engine conditions it is resistant to the high temperature. The main point, however, is the formation on the metal of the engine and valves of what is known as the graphoid surface, which is of an inert character and extremely resistant to heat and to corrosion. Even more valuable is the fact that this surface prevents the adhesion of hard films such as lead salts, which means the valves and valve seatings are efficiently lubricated so that sticking is eliminated. Colloidal graphite is in the form of particles so extremely minute that they are practically of molecular size, and for this reason they are dispersed in most liquids, not only lubricating oil but also petrol, for example.

Worn Valve Guides—Air Leakage

Owing to the constant sliding motion of the valve stems in their guides, under disadvantageous conditions of temperature and lubrication (and frequently with exposure to the abrasive action of road dust in the air), the valve stems and also the guides wear appreciably in the course of time. Usually after 12,000 to 15,000 miles' running both valves and stems show signs of wear; it is certainly necessary to remedy this state of affairs before 20,000 miles, if good running results are expected.

The effect of appreciable wear in the valve stem and guide is to give a bad seating to the valve, the side-play causing a slightly rounded instead of a flat seating; the valve will therefore have a choice of seating positions, and will not always bed down properly.

Another serious drawback is in connection with the leakage of air past the valve stem and into the engine (in the case of the inlet valves) without going through the carburettor. At slow engine speeds the throttle is nearly shut, and most of the suction is expended in drawing air into the engine past the valve stems, so that weak mixtures result and the engine will not run slowly. This valve-stem air leakage is one of the most difficult things to contend with in slow-running carburation.

Although we advise the fitting of new valve guides—and in some cases of new valves also—it is possible to obviate the disadvantages of worn valve stems and guides in so far as the leakage of air is concerned by fitting one or other of the devices now on the market for this purpose, and known as "*valve-stem sealers*."

Fig 228 shows the "Ayrtite" sleeve for the same purpose. A metal cylinder fitting over the valve guide is here kept in place by means of a flange on which the valve spring presses. A felt washer is fitted to the inside of the lower end of the sleeve, and this serves to seal the valve stem, for, being saturated with lubricating oil, it seals but does not impede the valve's movements. The ingenious motor mechanic will not find it difficult to devise other forms of valve-stem sealer of the felt washer and supplementary spring type should the occasion arise.

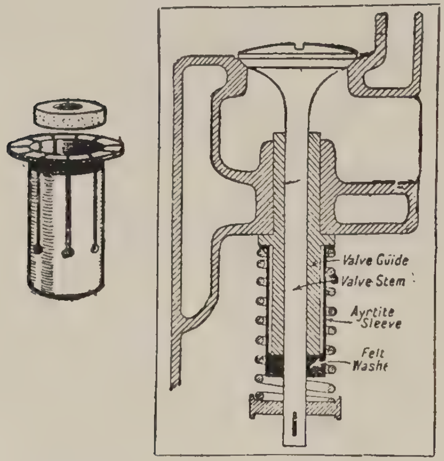


Fig. 228.—The "Ayrtite" Air-leak Preventer.

In the case of worn valve stems, the guides being fairly good, the only remedy for permanent results is to renew the valves; the guides being of cast iron, as a rule, do not wear so quickly as the valve stems.

In cases in which the valve stems are found to be worn appreciably —this can be tested either with a rod gauge or with a new valve—it is possible to reamer out the guide and to fit an oversize stem valve. In the case of certain standard makes of engines, special valve-guide reamers and fixtures are available, commercially, for this purpose.

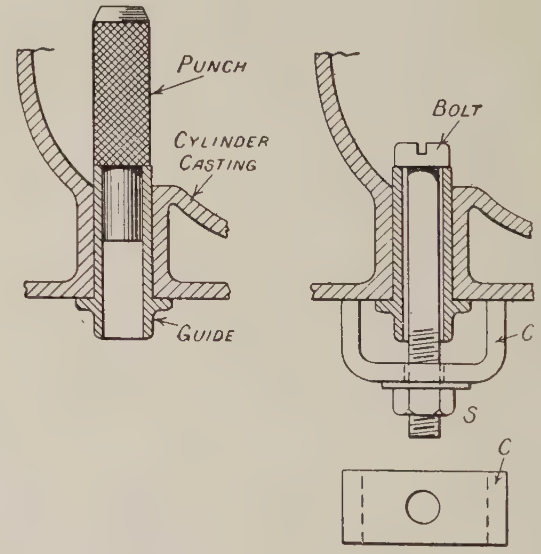


Fig. 229.—Showing Methods of removing Valve Guides.

Removing Valve Guides

With separate valve guides, it is better to remove and replace these when they become worn.

These valve guides are usually made of cast iron, and they are pressed into the cylinder casting tightly. After a time they will be found somewhat difficult to remove, but we illustrate two alternative methods which have always proved effective in this connection.

Fig 229 (left) shows the drift method, which is a straightforward one for removing the guides. The shouldered drift should be made especially for the valve guides to be removed, and it should have an overall diameter (i.e. on the upper portion) a little smaller than the valve guide's outer diameter. There should be sufficient length of the smaller diameter portion to ensure centrality and to prevent any tendency of the drift to deliver a side blow; there is a risk of breaking the valve guide in this way. A few sharp taps with a hammer on the head of the drift will usually start the valve guide.

The second method, illustrated in Fig. 229 (right), avoids the use of hammer blows, and therefore the risk of breaking the edges of the guide.

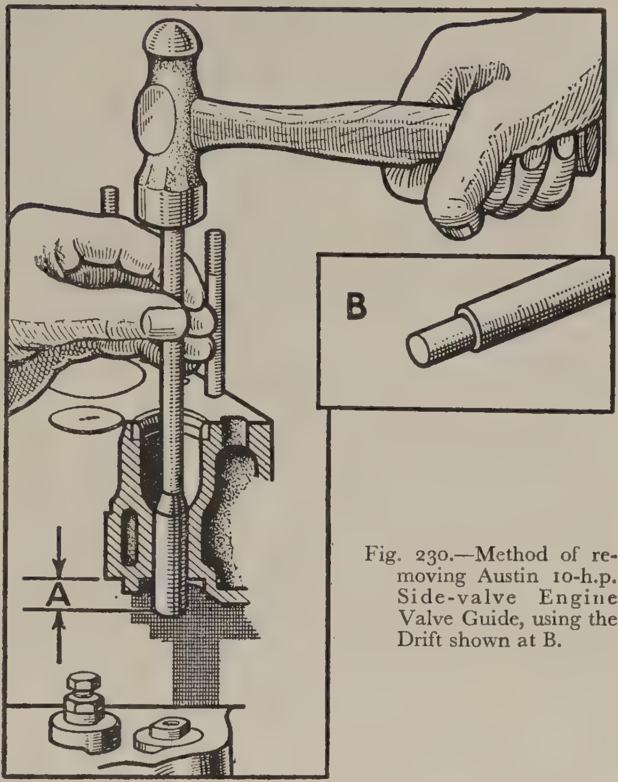


Fig. 230.—Method of removing Austin 10-h.p. Side-valve Engine Valve Guide, using the Drift shown at B.

It consists of a special bolt, with a slotted head—the latter to enable a screwdriver to be used to prevent turning—which is inserted in the valve guide, as shown. A stirrup piece C, made from a piece of steel strip, is held below the guide and forms a bridge, against which the nut is screwed. The effect of screwing up the latter is to cause the head of the bolt to draw the guide downwards. As shown, the stirrup piece does not allow the full length of the guide to be screwed, or rather pulled, out, since it is usually found that once loosened, it can be tapped out without trouble. The injection of petrol, benzole, or naphtha around the valve guide will usually facilitate its withdrawal.

The method of removing the Austin 10-h.p. engine valve guide is shown in Fig. 230, use being made of a drift B having a shouldered end. When the new valve guide is fitted it must protrude by the distance indicated at A, namely by $\frac{1}{2}$ in.

In the case of overhead valves the valve guide will be in the cylinder head, and the latter can readily be transferred to the bench for the purpose of removing the valve guides or inserting new ones. The method employed is illustrated in Fig. 231 in the case of the Austin A40 engine. It utilises a stepped drift, A, as before, to obviate it slipping off the guide and into the valve port. The guide should be driven out in the direction shown, *working on the plain* and *not the chamfered end.* The new guide should be forced into place in the same position, i.e. by inserting it through the valve seating and driving towards the top of the cylinder head. The final position of the valve guide is shown at B, Fig. 231, which indicates that the guide must stand $\frac{11}{16}$ in. above the cylinder head.

It is important after fitting a new valve guide to true up the valve seating and the valve by regrinding them in position.

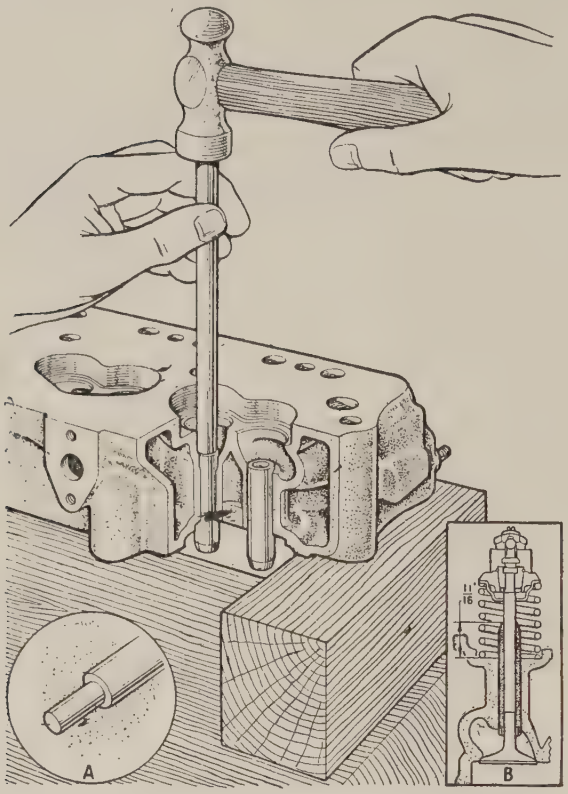


Fig. 231.—Removal of Austin A40 Engine Valve Guide.

Removing Valve-operating Tappets

The method of removing valve tappets is clearly illustrated by the example of the Austin 10-h.p. engine shown in Fig. 232. The tappet can only be removed if the tappet screw is first withdrawn. The tappet can be taken out with the fingers or with the aid of a screwed rod which will screw into the top of the tappet in place of the adjustment screw and enable it to be pulled up.

A Compression Valve Tester

A useful device for testing the gas-tightness of valves is shown in Fig. 233. The valve to be tested is placed in its valve seating on the cylinder and its spring and collar fitted in the usual way. The machined face of the compression chamber (Fig. 233) is placed on the cylinder-joint face—which must of course be clean for this purpose—a little oil being smeared around the machined face beforehand. The bulb is now fully compressed in the hand and the reading of the pressure gauge is watched. If there is any leakage at the valve and its seating, the pressure will fall fairly rapidly. If, on the other hand, the pressure remains practically constant or falls at a very slow rate, this indicates that the valve is a good fit on its seating. A device of this type is on the market.

Valve Clearances

The amount of clearance between the valve stem and rocker arm or tappet has an important influence both on the running and output of a petrol engine.

It is imperative always to maintain the proper clearances as recommended by the manufacturers.

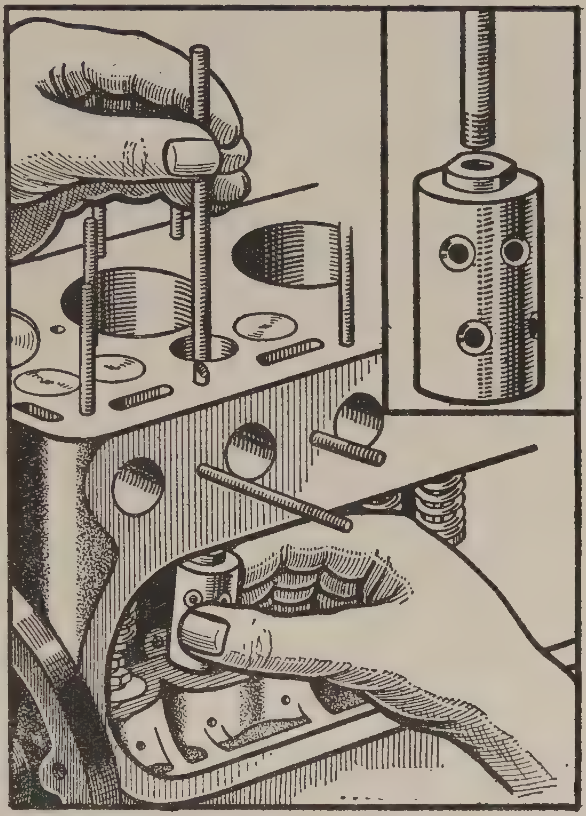


Fig. 232.—Removing the Valve Tappets.

Too much clearance causes incorrect valve timing in the first place; the valve opens later and closes earlier than it should do. The result of this is not only to upset the sequence or synchronism of the valve openings and gas flow, but to shorten the period of the opening, and thus to (1) reduce the amount of mixture taken into the cylinder, and (2) reduce the quantity of exhaust gas ejected. On the former count the power output will fall off, since there will be a reduced amount of mixture taken in at full throttle; on the latter count the engine will overheat, as the burnt gases cannot all escape. This in turn will cause preheating of the incoming mixture, with a further loss of efficiency. Apart from its effect upon the period of valve opening, too much clearance will mean a smaller valve lift, and for the same reasons as before a loss of power and overheating tendency. Finally, there will be a *noisier* operation, due to the increased velocity of impact of the rocker or tappet on the valve stem.

Too little clearance usually results in the valves not closing properly and, in the case of the exhaust valves, of an increased tendency for the valves to become burnt or pitted.

The valves should be adjusted, for clearance, when the engine is at *its proper working temperature*, and not when cold, since the expansion of the cylinders generally alters the clearances. In the case of *side-by-side valves*, there is usually a slight tendency for the clearance to become smaller as the engine cools, but in most cases this is practically negligible. With *overhead valves*, operated by external push rods and rocker arms, on the other hand, there is a greater total linear expansion of the cylinder block, and in consequence the clearance is appreciably smaller when the engine cools down. If the push rods work in holes bored through the cylinder block there will be less temperature effect on the clearances.

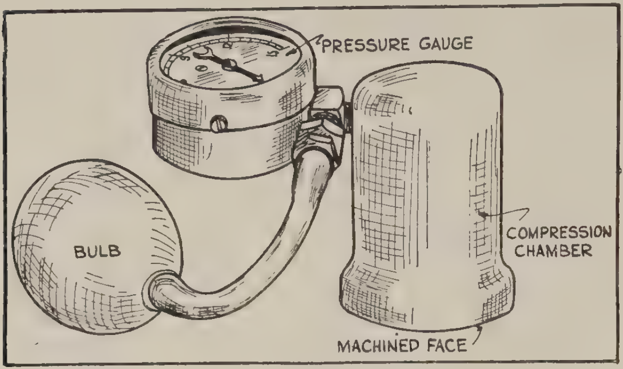


Fig. 233.—A Compression-type Valve Tester.

In the case of the earlier engine it was usual to operate with much smaller valve clearances than in more recent engines. Thus for side-valve engines the average inlet-valve clearance was ·003 to ·004 in., and exhaust-valve clearance ·004 to ·005 in. The reason for the greater exhaust clearance was on account of the hotter exhaust valve. Overhead valves were generally given more clearance on account of the greater linear expansion of the cylinder block. The inlet and exhaust clearance values for overhead valves were about ·004 to ·006 in. and ·005 to ·007 in. respectively.

In some engine designs the push rods worked in heated " tunnels " in the cylinder castings, and the differential expansion effects were then reduced, so that side-valve clearances could be used.

Overhead camshaft engines, which experience little valve differential expansion effects, have quite small clearances, namely ·003–·004 in. for inlet and exhaust valves.

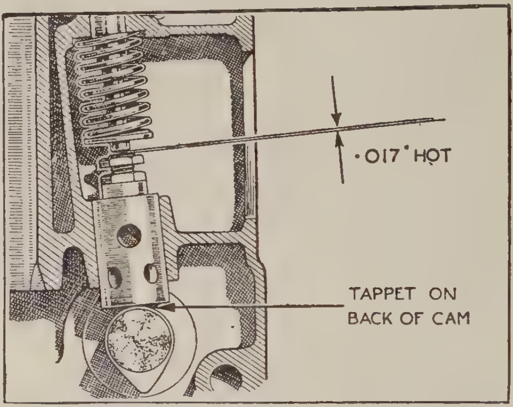


Fig. 234.—The Morris Minor Valve Clearance.

Modern engines employ special cam shapes which enable the valve-stem clearances to be increased, and there is then no risk of valve burning or falling off in power if the clearances are not checked very often. The usual inlet clearances are from ·015 to ·020 in. for side valves, and ·010 to ·015 in. for exhaust valves, but there are divergences from these nominal settings, as is shown in the accompanying data volume.

When consulting manufacturers' valve-clearance values, it should be ascertained whether these are for the *hot* or *cold* engine, as there is sometimes an appreciable difference between the two clearances. In the case of side-valve engines, e.g. the Morris ones, there will be slightly more clearance, namely by about ·001 in., when cold than when hot (Fig. 234).

Adjusting the Valve Clearances

The ordinary feeler gauge should be used to determine and set the clearances.

In the case of side-by-side valves the tappet usually has two hexagon heads, the lower one being a lock-nut and the upper the head of the adjusting screw. To adjust a valve, employ two thin set spanners. Hold one on the upper and one on the lower hexagon. Force the lower spanner in a counter-clockwise direction as viewed from above; this will release the locking screw and allow the upper spanner to be moved so as to operate the adjusting screw.

It is better to start with too much clearance, then insert the feeler gauge of the proper clearance, screw up the adjusting screw until it just begins to bind the feeler; then tighten the locking screw. Sometimes the latter operation will increase the clearance slightly; an allowance can be made for this. In tightening the locking screw, hold the adjusting-screw head in the other spanner to prevent it from moving; tighten the locking screw securely.

Make certain—by turning the engine and watching the valves lifting—that you have each cylinder on its compression or firing stroke, i.e. with both valves closed together, before attempting to adjust the clearances.

See that there is no oil or dirt between the tappet and valve stem; this will alter the clearance.

Finally, after setting all the clearances, crank the engine round a few times, and *then check all clearances again.*

Typical Examples of Valve Adjustments

Three examples to illustrate the method of adjusting the valve-stem clearances are shown in Figs. 235, 236, and 237 for side-valve, overhead push rod and rocker arm, and overhead camshaft modern engines respectively.

Referring to Fig. 235, this shows the Humber Snipe and Pullman valve-clearance adjustment. The method recommended is to rotate the engine by the starting handle until the corresponding valve, on the corresponding cylinder, is at full lift. *The corresponding cylinders* are 1—6, 2—5, and 3—4. As an example, when adjusting No. 1 inlet-valve tappet see that No. 6 inlet valve is fully open, then No. 1 will be fully closed, and so on. Use three spanners, as shown

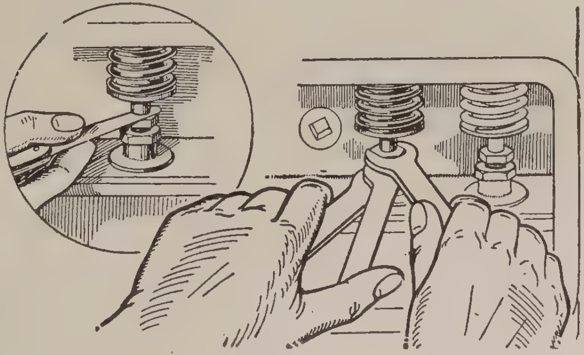


Fig. 235.—Adjusting the Humber Snipe Valve-stem Clearances.

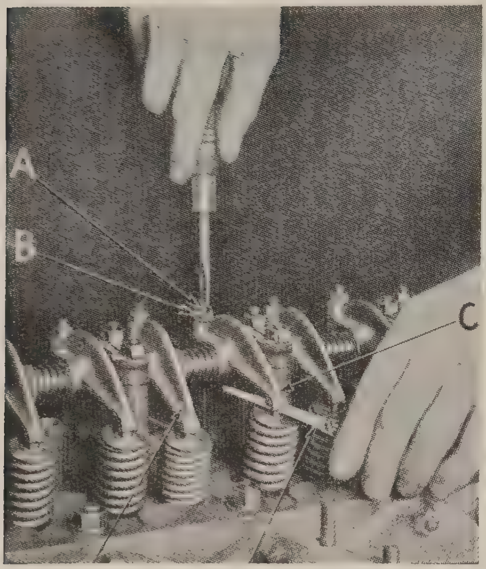


Fig. 236.—Adjusting Lanchester Overhead-valve Clearances.
A, Adjusting Screw. B, Lock-nut. C, No. 4 Rocker Arm (up).

in Fig. 235 (right), for holding the tappet, the lock-nut, and tappet-adjusting screw respectively.

The correct clearances (cold) should be ·010 in. for inlet and exhaust valves.

The method of adjusting the overhead-valve clearance in the case of the Lanchester Ten engine is shown in Fig. 236. The lock-nut on the screw at the push-rod end of the rocker arm is unscrewed, and the screw itself is tightened or slackened with a screw-driver to reduce or increase the clearance. Afterwards the lock-nut is tightened and the clearance again checked with the feeler gauge.

The following is a useful table showing which valve should be fully lifted when the other corresponding one is fully closed. The valves are numbered from No. 1 at front (radiator) end to No. 8 at the scuttle:

With No. 8 valve fully open, No. 1 is fully closed.
With No. 7 valve fully open, No. 2 is fully closed.
With No. 6 valve fully open, No. 3 is fully closed.
With No. 5 valve fully open, No. 4 is fully closed.
With No. 4 valve fully open, No. 5 is fully closed.
With No. 3 valve fully open, No. 6 is fully closed.
With No. 2 valve fully open, No. 7 is fully closed.
With No. 1 valve fully open, No. 8 is fully closed.

The same order applies for all four-cylinder engines with the same firing order, namely 1, 3, 4, 2.

The Lanchester Ten valve clearance is ·012 in. for both inlet and exhaust valves. It is recommended that the clearances should be checked after the first 500 miles and then at every 6,000 miles.

An example of an overhead camshaft engine, namely that of the Morris Six (also the Wolseley Four-Fifty), valve-clearance adjustment method is shown in Fig. 237. Having

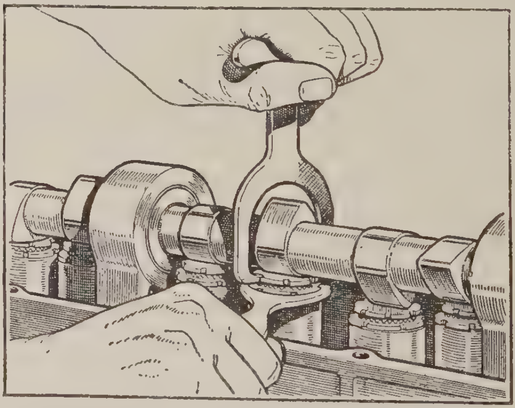


Fig. 237.—Adjusting Overhead Camshaft Valve Clearances (Morris and Wolseley).

removed the overhead-valve cover to expose the camshaft and valve collars, it will be noted that the mating faces of the valve-adjuster head and the spring cap are serrated, and that as each adjuster is screwed in or out of the valve these serrations will be plainly felt. Each serration represents an adjustment of ·001 in. To adjust: hold the valve-spring cap with the straight-handled ring spanner (this is shown below in Fig. 237) in order to prevent the valve from rotating. Then straddle the camshaft with the T-headed spanner and engage the slots in the adjuster head. Screw the adjuster in or out until the clearance (hot) is ·015 in. An additional ·001 in. should be allowed if the valve is cold. The valve-stem adjustment should be checked every 6,000 miles. The method of adjusting the Standard Vanguard overhead valves is illustrated in the Plate facing page 202.

Adjusting the Austin Oil-cushioned Overhead Valves

The more recent overhead-valve Austin engines are fitted with oil-cushioned push rods and rockers for silencing purposes, as shown in Fig. 238. It is necessary to break down the oil film between the rocker and top of push-rod socket by exerting pressure on the rocker as shown at A, whilst measuring the valve clearance at B with a ·015-in. feeler gauge.

Pressure should be applied with the screw-driver blade at A whilst slackening back the lock-nut. Then raise or lower the adjusting screw by rotating the screw-driver blade, maintaining pressure on the latter whilst checking the clearance at B. Then tighten up the lock-nut.

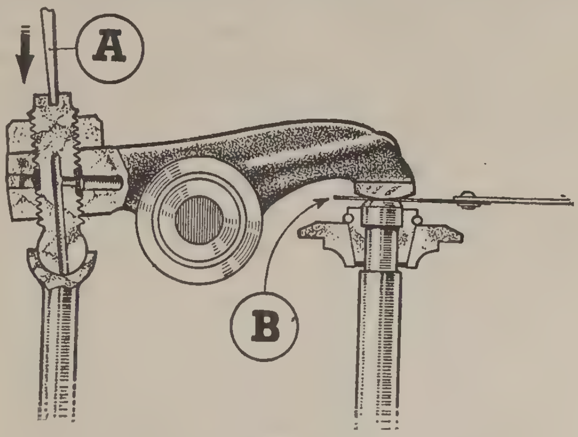


Fig. 238.—Adjusting Austin Oil-cushioned Valves.

Note that the clearances should be adjusted when the engine is hot.

The Ford Valves

The Ford 8-h.p. and 10-h.p. engines are fitted with special valves having expanded valve-stem ends; it is therefore impossible to withdraw the valves through the valve guides in the usual manner. Fig. 239 illustrates the Ford valve and its components. The valve end E is expanded in order to give a relatively large area for the tappet contact since there is no adjustment provided here. The valve collar is of horse-shoe shape and the valve guide is split, being made in two symmetrical halves as shown at S.

The valve spring and collar can be removed with the aid of a spring compressor in the usual way. Before the valve can be removed, it is necessary to lift it in its guide, and then, with the aid of a brass or copper drift—inserted between the head of the lifted valve and the valve seating—to drive the two halves of the guide downwards. The guides can then be taken apart and removed, when the valve stem will pass through the valve-guide hole.

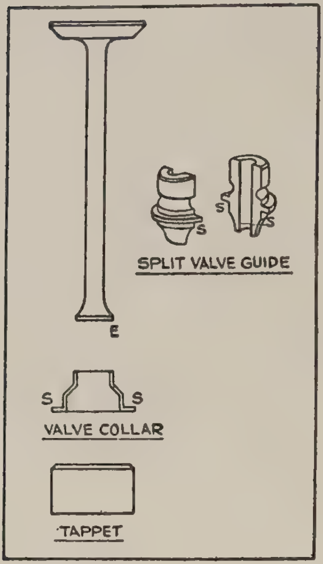


Fig. 239.—The Ford Valve and Guide.

The order of the valves in the four-cylinder block is as follows, as reckoned from the radiator end: E, I, I, E, E, I, I, E, where E and I are the exhaust and inlet valves, respectively.

Special tools for removing the Ford split-guide pattern valves are illustrated in Figs. 240 and 241. The tool shown at A is a cranked drift that is used for driving out the split guides. The partly cut hollow metal tool depicted at B is employed for the same purpose. It is inserted from the side with the valve lifted—after taking away the valve spring—and is then tapped downwards in order to force the split guide out of the cylinder block. A considerable amount of time is saved by the use of such tools.

When removing Ford valves it is important to ensure that each valve is in its fully closed position. Each valve, guide, and spring should be kept together after removal; the valve heads should be checked for identification markings before removing the valves.

The use of makeshift tools for removing the guides is not recommended, as there may be some risk of bending or damaging the surface of the valve stems. After regrinding the valves and replacing them in their original positions, but without their springs, the clearances should be checked with the heads of the valves pressed down on their seatings.

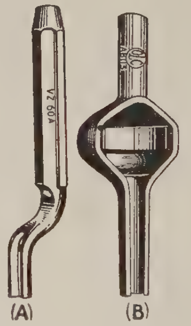


Fig. 240.—Tools for removing Ford Valve Guides.

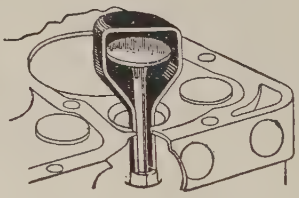
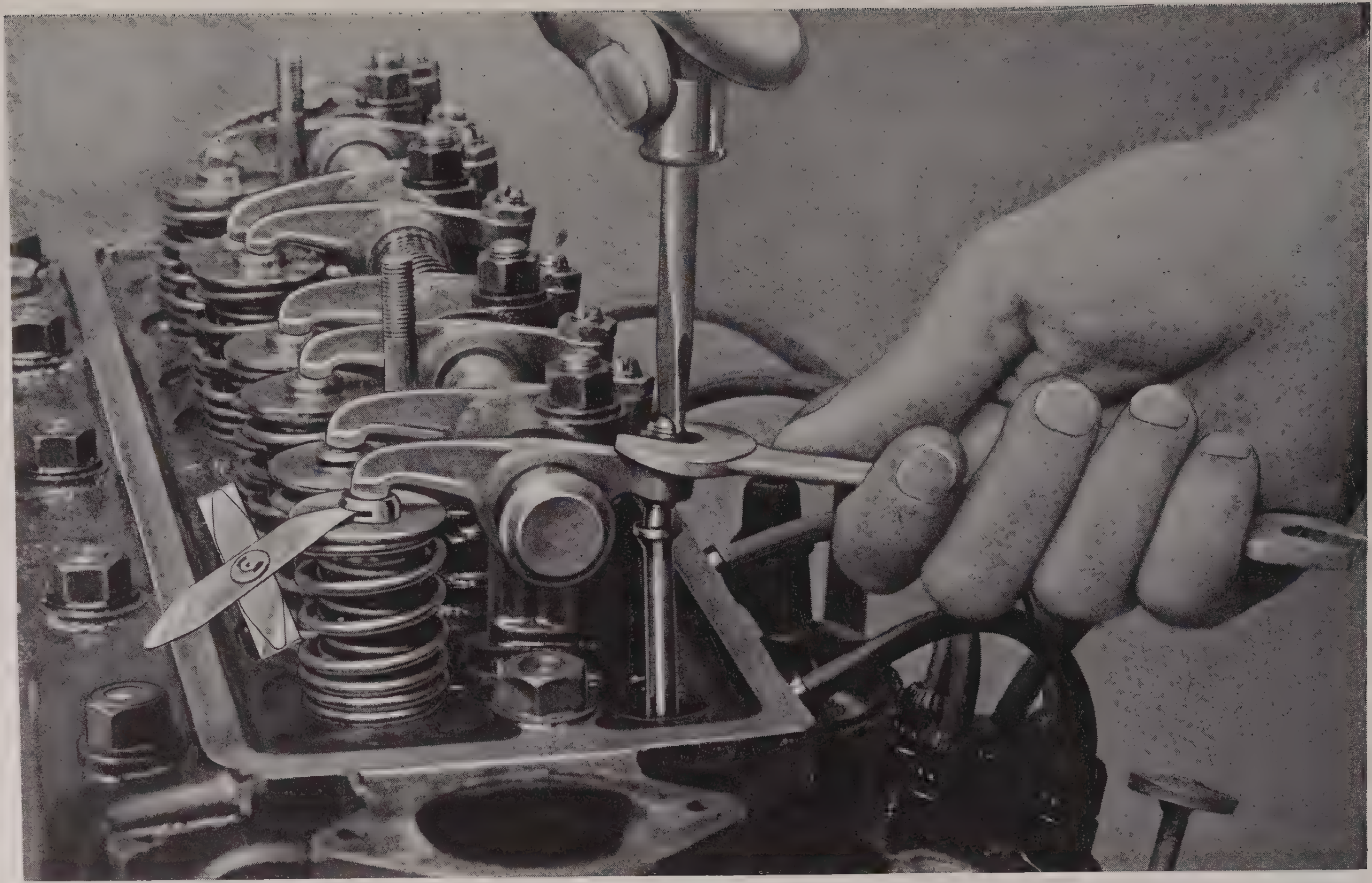


Fig. 241.—Another Type of Valve-guide Remover.

The correct clearances should lie between ·0115 and ·0135 in. for both inlet and exhaust valves. If the clearance is more than ·0135 in., the valve face or seating (or both) should be ground to reduce the clearance. If less than ·0115 in., the end of the mushroom stem must be butt ground accordingly. Certain designs of valve-face grinding machines, e.g. the Van Norman, make provision for grinding the ends of Ford valves to a micrometer-rod gauge.



CHECKING AND ADJUSTING VALVE CLEARANCES ON STANDARD " VANGUARD " ENGINE. THE LOCKING NUT IS HELD BY THE SET SPANNER AND THE ROCKER-ARM SCREW ADJUSTED WITH A SCREWDRIVER UNTIL THE VALVE CLEARANCE, AS TESTED BY THE FEELER GAUGE, SHOWN ON LEFT, IS ·010 in. (COLD) FOR BOTH INLET AND EXHAUST VALVES.

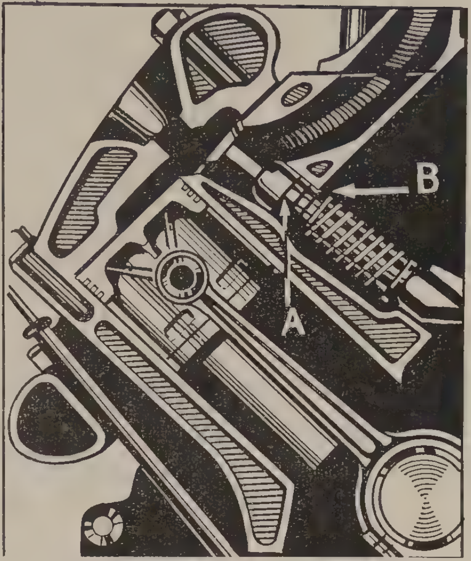


Fig. 242.—The Ford V-8 Valve Unit. A—Valve Guide. B—Retaining Cotter.

The Ford service depots are provided with special jigs for grinding the valve-stem ends to the exact clearance values. In the case of the later model Ford V-8 engines (Fig. 242), the complete valve, spring, collar, and valve-guide unit can be removed bodily from the engine by first compressing the upper coils of the spring and then pulling out the cotter B, which will be found near the valve guide (Fig. 243).

Valve Timing

It is seldom necessary for the garage engineer to alter or to experiment with the timing of an engine, since the settings of the makers are almost invariably the best. It sometimes happens, however, that after an engine has been completely dismantled and is being reassembled there is some doubt as to the correct valve timing when the timing gear is put back. Let it be fully understood at the outset that in

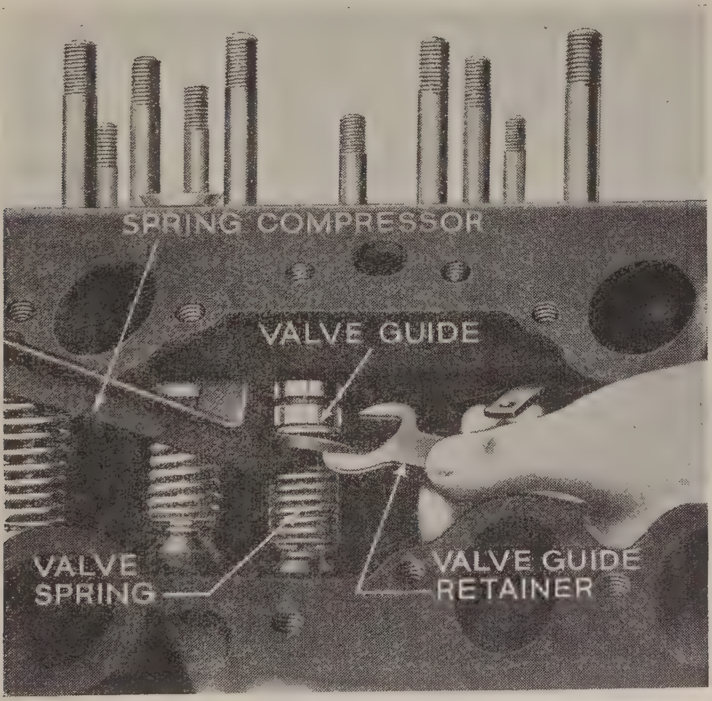


Fig. 243.—Removing Ford Valve Assembly.

such cases it is usually only necessary to find the correct moment of *opening* of one valve, as the *shape* of the cam determines the actual period of opening, and this cannot be changed in a given engine. The only thing the amateur can do is to alter the point, relatively to the piston's position, at which the valve starts to open.

Let us consider the case of a four- or six-cylinder engine. There is one camshaft having four (or six, in the case of a six-cylinder engine) inlet and four (or six) exhaust cams, usually cut from the solid on the shaft, and therefore integral with and immovable from it. In these cases it is only necessary to find the correct point at which *any one valve* should commence to lift, or open, and to alter the mesh of the driving gear or chain on the sprockets from the crankshaft to the camshaft, until this valve opens when the piston, or crankshaft, is in the relatively correct position. Having set one point of opening of one valve, all the rest will be correct.

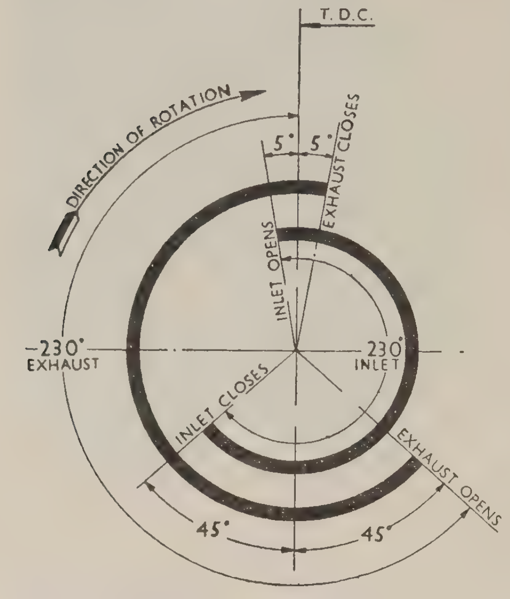


Fig. 244.—Typical Valve-timing Diagram (Austin).

The maker's valve-timing diagram must be consulted to find the correct point of opening. To take a specific instance, Fig. 244 represents the valve-timing diagram of a typical four-cylinder engine of high output and excellent performance.

If we consider any particular cylinder of the engine, then the crank associated with it will be in the positions shown by the radial lines from the centre of the circle or circles. It will be seen that the inlet valve opens at 5° before the piston reaches its top dead centre (T.D.C.), and it remains open until 45° after bottom dead centre (B.D.C.). The total crank angle corresponding to the inlet valve opening will be $5^\circ + 180^\circ + 45^\circ = 230^\circ$. The exhaust valve opens at 45° before B.D.C., and remains open until 5° after T.D.C., corresponding to a crank angle or period of $45^\circ + 180^\circ + 5^\circ = 230^\circ$, so that both valves have equal opening periods.

To set the valve timing it is necessary first to rotate the crankshaft by hand, with the timing gear (or camshaft drive) disconnected, until No. 1 piston (nearest radiator) is on its T.D.C.

Before proceeding further make sure that *the tappet clearance of No. 4 inlet valve is set* to the manufacturer's recommended value—in this case ·008 in. As the inlet valve opens at 5° before T.D.C., it will be necessary, in the absence of any further guide, to turn the flywheel *back* through an angle of 5°. In the present instance the flywheel diameter is $12\frac{13}{16}$ in., and it can be shown by calculation[1] that 5° is equivalent to a distance of $\frac{9}{16}$ in. measured along the flywheel rim from the T.D.C. position.

Actually, in this example, as in many other instances of modern car engines, the manufacturers have made it an easy matter to reset the valve timing by spot marking the sprockets on the crankshaft and camshaft respectively, as shown by the two black spots at the roots of the sprocket teeth in Fig. 245. In order to time the valves correctly it is necessary only to set the spots opposite to one another, i.e. in line as shown, and then connect up the chain drive, but without moving either the crankshaft or camshaft.

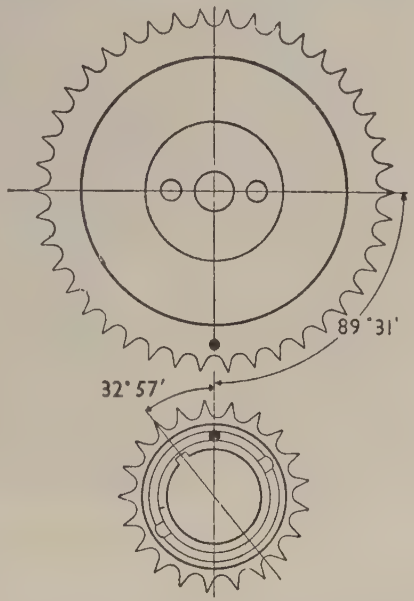


Fig. 245.—Method of marking Chain Sprocket Wheels for Valve-timing Purposes (Austin).

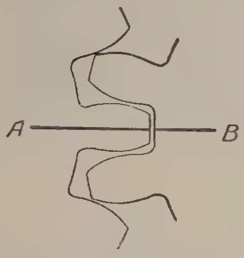


Fig. 246.—Method of marking Gear Wheels.

In the case of vehicle engines that employ gear-wheel drives for the camshaft it is usual to mark pairs of mating gears in the correct positions for valve timing. Generally, this is effected by means of a line AB (Fig. 246) across the crest of one tooth and the root portion of the corresponding mating gear.

The Daimler and Lanchester Engines

The Daimler and Lanchester engines employ a simple and ingenious method of setting the valve timing. The procedure is as follows: turn the crankshaft until the T.D.C. mark on the flywheel is at the top and opposite the peg in the flywheel casing. The camshaft, being disconnected, is turned until a suitable tommy-bar can be inserted in the hole in the camshaft wheel (Fig. 247), so that it locates with the hole in the crankcase. When this has been done, the camshaft will be in its correct position relatively to the crankshaft for the proper valve timing. The camshaft driving chain should then be replaced with its connecting link.

The Morris Engines

In the case of the Morris engines—the timing gear of which is shown in Fig. 248—the camshaft sprocket, having twice the number of teeth of the engine or crankshaft one, is driven by means of a roller chain. One tooth of each sprocket is marked with the letter "T," as indicated in Fig. 248. If the roller chain be examined, it will be found that there are

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[1] See page 154.

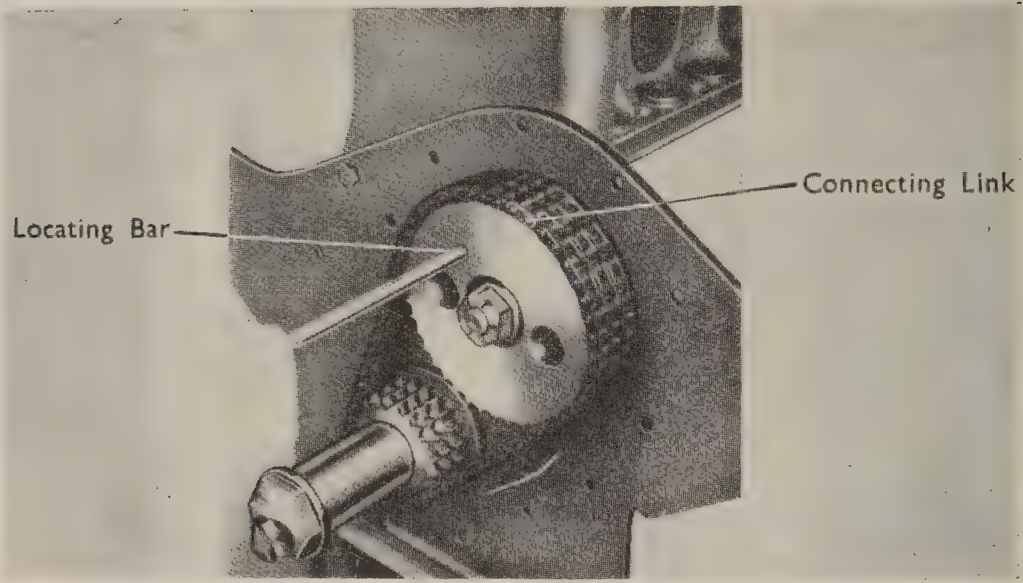


Fig. 247.—Method of timing Daimler and Lanchester Engines.

two bright links in different positions along its length. In order to time the valves correctly, all that is necessary is to rotate the camshaft independently of the crankshaft to a position such that the bright links come opposite the "T" marks on the sprockets. The camshaft will then be in its correct position relative to the crankshaft.

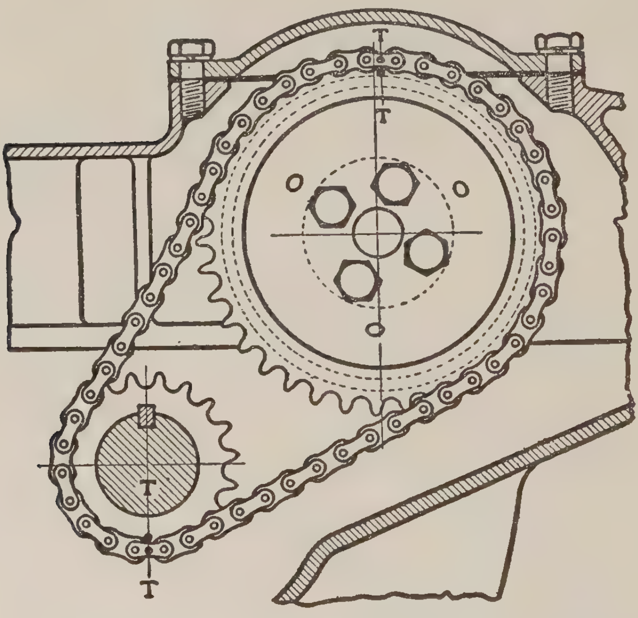
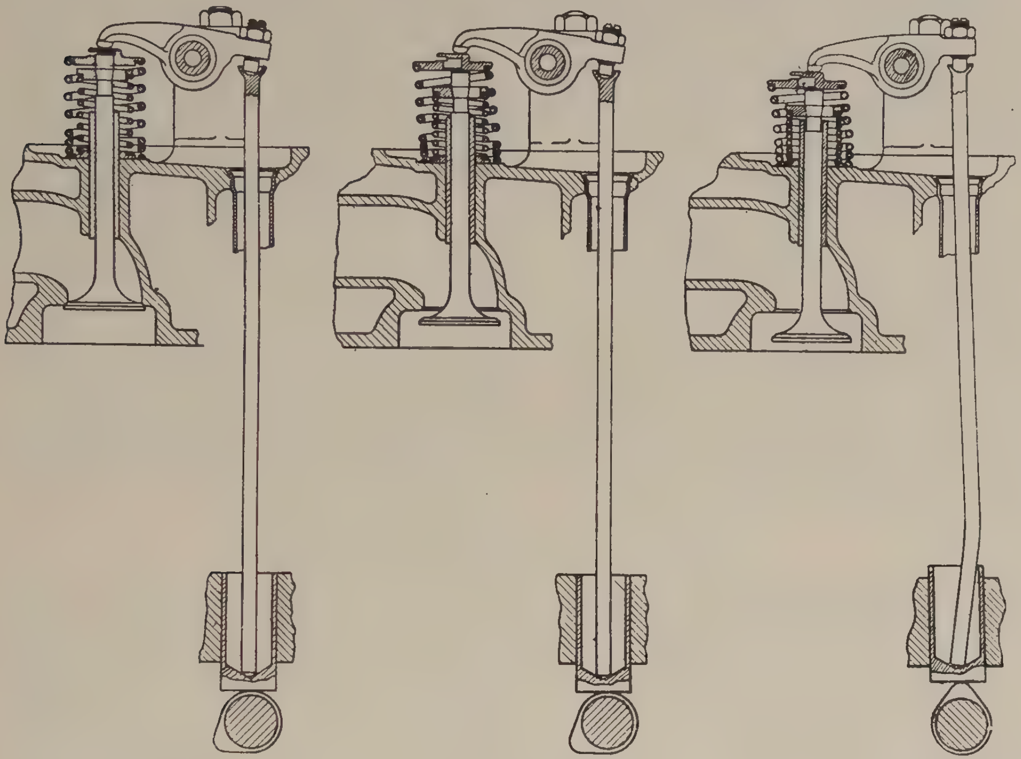


Fig. 248.—Method of timing Morris Engine, using bright Chain Links, shown at "T," which are set against "T" Marks on Chain Sprockets.

The Vanguard Engine

This is a four-cylinder engine having overhead valves operated by push-rods and rocker arms. The valve-timing diagram of this high-efficiency engine is shown in Fig. 249. It will be observed that the inlet valve opens at 10° before the piston reaches its top dead centre, whilst the exhaust valve closes 10° after the top dead centre. This means that both inlet and exhaust valves are open together over a crank angle period of 20°. This method is termed *valve overlap*, and is employed to give better cylinder charging, since it employs the inertia effect of the exhaust gases to create a partial vacuum in the cylinder in order to increase the inlet charging effect. It will be observed that the opening periods for both the inlet and exhaust valves are 240°.



(1) Valve Springs correctly fitted, precautions: Firstly—Screw the Adjusting Screws well back. Secondly—Centre the Caps correctly over Valve Stems whilst tightening down the Rocker Pedestals. Finally—Adjust the Valve Clearances.

(2) Rocker Pedestals have been tightened down without ensuring that the Valve Cap was correctly fitted.

(3) With the Valve Caps fitted as in (2) and the Crankshaft rotated, the inner Valve Springs will go "solid" and the Push Rod will be forced into a bent condition.

A similar condition would result if the Adjusting Screw was screwed at least $\frac{3}{32}$ in. further down, even though the valve Cap was correctly fitted.

Fig. 249.—Method of fitting Standard Vanguard Valve Rocker-shaft Assembly.

In regard to the inlet valve opening position, it may be noted that 10° of crank angle is equivalent to ·035 in. of piston movement.

Unless marked, the T.D.C. of No. 1 piston can be found with the aid of a rod some 7–8 in. long inserted through the sparking-plug hole. The procedure for timing the valves of the Vanguard engine when no markings exist is as follows:

1. Remove the rocker shaft and withdraw outer valve springs, but not

spring caps, on Nos. 1 and 4 cylinders. Refit rocker shaft, taking steps to ensure that the outer spring caps register properly with the valve stem as the pedestal brackets are tightened down, and that damage is not caused by misplacement of these caps, as indicated in Fig. 249.

2. Set valve-rocker clearances for Nos. 1 and 4 cylinders to ·014 in., which is the valve-timing clearance.

3. Turn the crankshaft round until Nos. 1 and 4 pistons are on T.D.C. This position may be found, either by placing the keyway in the crankshaft vertically downwards, or alternatively by the employment of a small diameter rod 7–8 in. in length inserted through the sparking-plug hole, as mentioned earlier.

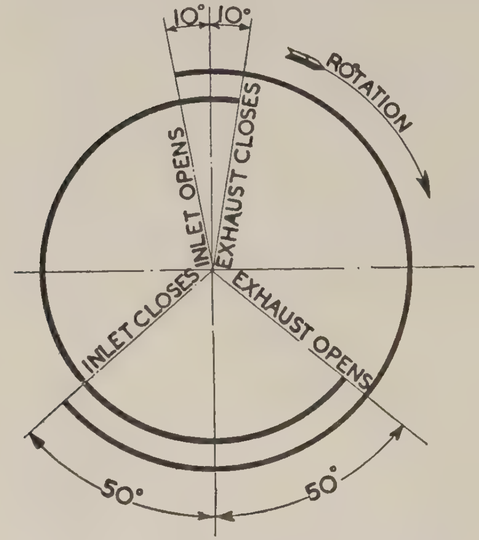


Fig. 250.—The Vanguard Engine Valve-timing Diagram.

4. Rotate the camshaft until the exhaust valve and inlet valve are at the point of balance. In this position the exhaust valve will just be about to close and the inlet valve be just commencing to open. From Fig. 250, which gives the valve-timing diagram, it will be observed that the inlet valve opens 10° before T.D.C. and the exhaust valve closes 10° after that point (·035 in. on piston stroke). The only difficulty with the setting of this timing is the location of T.D.C. and the travel of the piston. When setting the valve timing, the actual opening and closing points of the inlet and exhaust valves are not so important as that these should occur by equal amounts (10° before and after T.D.C.).

Having set the valve timing correctly, the timing gears and camshaft end should be marked. This may be done by laying a straight-edge across the faces of the two sprockets and scribing a line radially across their faces. To ensure correct positioning of the camshaft for future timing operations make a centre-punch mark on the end of the camshaft through a setscrew hole, and mark the face of the camshaft wheel in a similar way.

Timing the Valves of Other Engines

It has been possible to deal only with the methods of timing the valves of a few typical engines amongst the large number of vehicle engines in current use. In other cases the timing gears or chain sprockets should always be examined for distinguishing timing marks, and the flywheel rims also, both for T.D.C. and timing marks.

Reference should also be made to the data volume, which gives the specifications of a large number of motor vehicles.

Timing Unmarked Engines

In some cases, no markings will be found on the timing-gear wheels, and if there is no timing diagram available or other information to hand, it may be necessary to adopt the trial-and-error method.

Fortunately, however, this need not provoke much difficulty, for it is a fact that most petrol engines are timed with their inlet valves opening either on, or very near to, top dead centre, and their exhaust valves closing on or near to top dead centre.

As a first trial, set the inlet valve to just start to lift when the piston is on top centre, and if the exhaust valve is operated by a separate cam, as in some motor-cycle engines, set it to just close on the top centre of the *second*, or *next but one*, revolution past the inlet valve opening one (for there is one inlet and one exhaust period every two revolutions of the crankshaft).

If the engine does not appear to be giving its full power with this setting, alter the timing-wheel meshing *by one tooth* or, for timing chain drives, by one sprocket tooth, so that the inlet valve opens just a little before top centre. This procedure should be repeated until maximum output is obtained.

Timing Diesel-engine Valves

The accurate timing of the air inlet and exhaust valves of Diesel engines is more important than for petrol engines, the reason being that in these high-compression-ratio engines the pistons come very close to the metal of the combustion chamber when on their top dead centres. Moreover, as the valves of practically all vehicle Diesel engines are in the cylinder head, any mistake in valve timing may cause the valves to open and foul the cylinder head, thereby causing serious damage. It is here proposed to describe in detail the operation of timing the valves in the case of the well-known A.E.C. direct-injection 7·7-litre engine. The camshaft can be set in its correct position in relation to the crankshaft, without breaking the timing chain, as follows: remove the clip securing the breather pipe to the front air-inlet pipe. Remove the timing-chain cover and the two bolts securing the camshaft gear-wheel to its hub. Then rotate the camshaft to obtain the correct setting, as described a little later. Lock the camshaft gear-wheel and hub by inserting the two bolts into the two sets of holes lying opposite each other. Tighten the bolts and secure with split pins.

The firing order is 1, 4, 2, 6, 3, 5 (numbers taken from the *fan end*).

To time the camshafts, proceed as follows:

1. Set the flywheel T.D.C. 1 mark in line with the timing pointer on the engine sump.

2. Remove the two locking bolts from the camshaft sprocket (see Fig. 261 on page 218) and set camshaft with No. 6 exhaust and inlet valves just balanced, i.e. inlet just opening and exhaust just closing.

3. Set valve clearances, making sure that the *tappets are on backs of cams*, and insert the two locking bolts in the two holes lying opposite in the camshaft gear-wheel and its hub. Do not put any oil in the tappet or push-rod cups, and when checking the valves for opening point turn the flywheel and at the same time spin the push rods. *As soon as the inlet push rod is too tight to spin*, the inlet valve will be at opening point, and as soon as the exhaust push rod spins, the exhaust valve will be closing.

4. Rotate flywheel in a clockwise direction, looking from the fan end. No. 6 cylinder inlet valve should open $\frac{3}{8}$ in. before the T.D.C.1 mark measured on the flywheel; exhaust valve should close 1 in. after the T.D.C.1 mark measured on the flywheel. If incorrect within plus or minus $\frac{3}{8}$ in., remove camshaft gear locking bolts, rotate camshaft to advance or retard as required, then refit the locking bolts, tightening solid and locking with split pin. *If the timing is more than two teeth out the engine cannot be turned, as the valves will hit the piston heads.*

5. Replace the timing-chain case top cover, exercising care that the oil seal fits into the recess in the cover.

6. Run the engine, and finally set the tappet clearances with the engine hot.

Notes on Valve Timing

Before setting the valve opening and closing positions, by the usual method of timing the opening of the inlet valve of No. 1 cylinder, the correct (cold) clearance between the valve stem and its tappet or rocker arm should be given.

If a feeler blade of slightly greater thickness, say about $\frac{1}{1000}$ in. more, be inserted between the valve stem and tappet and a pull be exerted sideways on this whilst the camshaft is turned slowly, with the crankshaft fixed on its T.D.C. or valve-opening angle, as the case may be, the exact moment of the inlet valve-opening can be felt by the greater pull required to move the feeler blade, i.e. it will become " nipped " solidly at this point.

In the case of big-clearance valves, e.g. the Morris engine ones, it is advisable to reset the valve timing by the marks on the timing gears ; this method is recommended by the engine manufacturers as the special design of the cam prevents accurate setting by the usual method of watching the point of the valve opening whilst rotating the camshaft.

Timing-gear Chain Drives

The method of driving the half-speed, or camshaft, and other items such as the ignition unit, water pump, and dynamo by means of gear-wheel trains has been almost superseded in more recent engines by the chain-drive system.

There are, however, exceptions, notably in the case of certain commercial-vehicle engines, in which the camshaft is gear-driven, a typical example being the Leyland Comet engine, the timing gears of which are shown in Fig. 251. Here the crankshaft is fitted with a small helical gear, which meshes with a central idler gear having twice the number of teeth, so that it runs at half engine speed. This idler drives the camshaft on the left through an equal-tooth helical gear, and the vacuum pump and fuel-injection pump on the right through a similar size gear-wheel. The directions of rotation are shown by the arrows on the gear-wheels. *The camshaft is timed* by first setting No. 1 piston on T.D.C. with the inlet valve opening. The gear on the camshaft is then fitted so that the arrow on the face and the arrow on the timing back-plate are in line (Fig. 251), i.e. 90° to the top face of the engine block when the gear is located on the dowel in the camshaft end. If Fig. 251 be examined it will be seen that there is a small arrow at A on the camshaft gear and a fixed arrow at B on the back-plate; these two arrows should be in line.

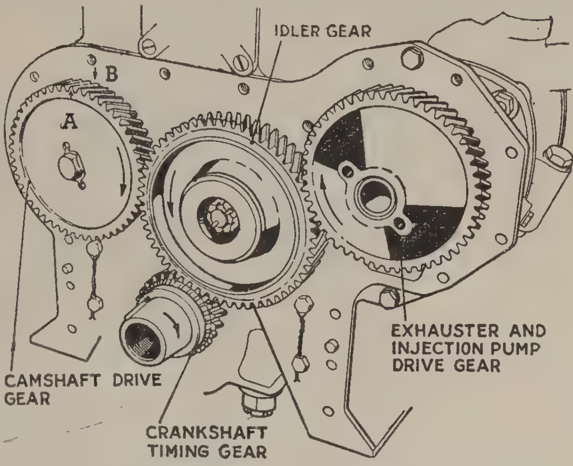


Fig. 251.—Timing Gears on Leyland Comet Engine.

Although the silent-chain drive, with its succession of pointed links, had a long period of popularity, it was finally displaced by the roller chain in later engines. The silent chain had the merit of being fairly quiet in action and self-adjusting to a certain extent, but it was much heavier than the roller chain; with the general demand for lighter engines, the latter type came into favour. The roller type of chain is very efficient and quiet in action, so that it is probably the most satisfactory form of drive for the camshaft and other auxiliaries. The earlier practice was to make the same chain drive all of the auxiliary components in addition to the camshaft. In modern engines the dynamo is driven by the fan-pulley V-belt, so that a simple type of chain drive is then possible. Roller chains used for motor-vehicle engines are of the *single pattern* for the smallest car engines, *double* for medium sizes of car engines and certain larger types, and *treble* for the largest car engines and practically all commercial vehicles.

A typical example of a silent chain inverted-V drive for the camshaft as employed on modern Dodge commercial-vehicle engines, in preference to roller chains, is illustrated in Fig. 252. The various components are denoted by the numbered arrows, and are described below the illustration. The camshaft is mounted in four bearings, of which Nos. 1, 2, and 3 are detachable steel-backed whitemetal-lined, whilst No. 4 is machined in the cylinder casting. To time the Dodge engine, it should be noted that the two timing marks, 6, should be brought into line with the centres of the camshaft and crankshaft. When refitting the timing chain it should be pointed out that the set-screw holes are offset so that the sprocket can be fitted only in one position.

Fig. 253 shows the timing gear chain drive of the Jowett engine. It will be observed that there is an additional chain sprocket, F, fitted for the purpose of chain tension adjustment. Excessive slackness is indicated by undue noise, and the adjustment can be made with the engine running slowly by means of an adjusting screw provided for the purpose. The lock-nut of this screw should be loosened beforehand. The screw should be turned in an anti-clockwise direction to tighten the chain, i.e. until the noise ceases. Then turn the adjusting screw back one-quarter of a turn and lock in position with the lock-nut. *There should not be more than $\frac{1}{8}$ in. side play of the timing chain* when correctly tensioned.

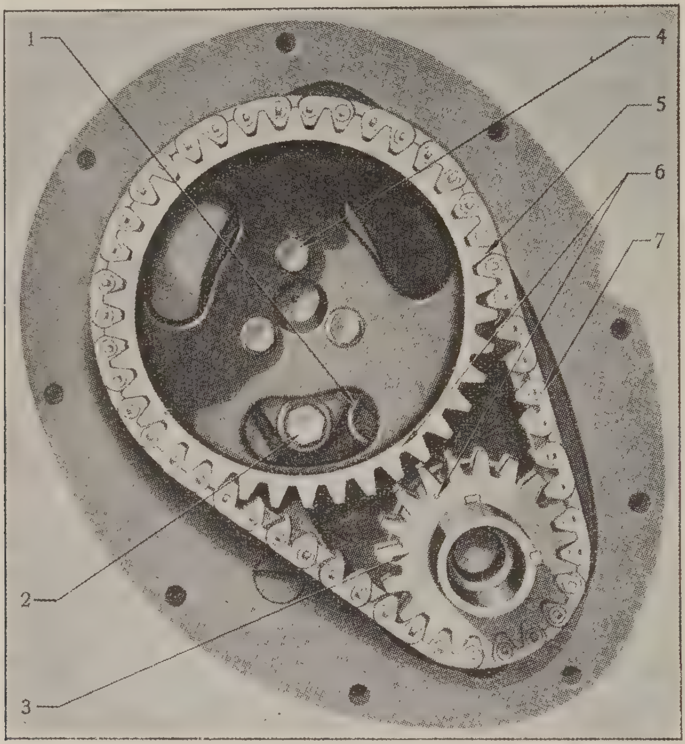


Fig. 252.—The Dodge Commercial Engine Timing Chain and Sprockets.
1. Camshaft-sprocket Oil Tube. 2. Thrust-plate Screw. 3. Crankshaft Sprocket. 4. Camshaft-sprocket Screw. 5. Camshaft Sprocket. 6. Valve-timing Marks. 7. Inverted-V Timing Chain.

In some cases the dynamo-drive spindle bearing is made eccentric for chain-tightening purposes. In other instances, a jockey-chain sprocket having an eccentric bearing is employed.

The method of tightening the chain drive in the case of the Armstrong-Siddeley is shown in Fig. 254. Here the dynamo is bolted on to the timing-case bracket by means of three nuts and studs. The holes for the two upper studs A are slotted, whilst the lower one (not shown) acts as a pivot, so that the dynamo rocks bodily about this stud. When moved away from the engine, the chain is tightened, and when towards it, is slackened.

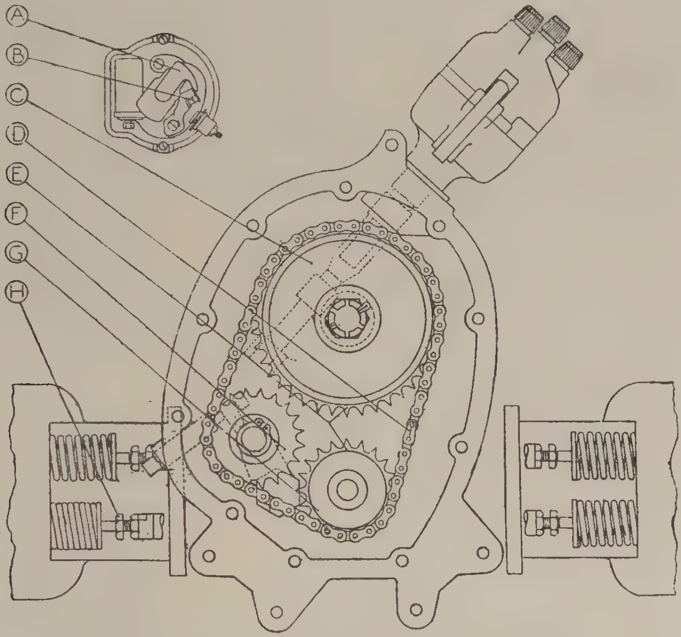


Fig. 253.—The Jowett Timing Chain and Sprockets.

A—Contact-breaker Segment just firing near-side Cylinder. B—Contact-breaker Points just breaking in Distributor. C—Camshaft Sprocket. D—Spring Link for Chain Removal. E—Marked Teeth on Crankshaft and Camshaft Sprockets. F—Chain-adjuster Sprocket. G—Crankshaft Sprocket. H—Off-side Cylinder Inlet Valve just opening.

An inspection hole B, normally covered with the plug D, is provided for observing the chain. The nut C is on the end of the dynamo spindle and holds it to the driving-chain sprocket.

The water pump, it should be mentioned, is driven at the other end of the dynamo by the armature-spindle extension. Should the timing chain have been removed at any time, it will be necessary to reset the valve and ignition timing.

The radiator starting-handle dog, fan pulley, and the damper have most likely been removed already, so to perform this operation turn the crankshaft and camshaft by hand until the line on the flange of the former and the

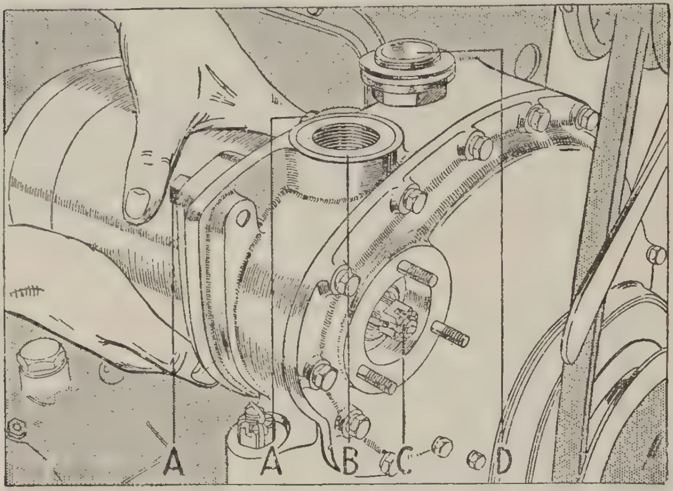


Fig. 254.—Method of tightening Chain Drive on Armstrong-Siddeley Engine.

O on the face of the latter are opposite and adjacent to one another. Thread the chain over the crankshaft wheel (Fig. 255) and, taking care that the camshaft wheel does not move, fit the chain round it from the top. The joint in the chain should be placed at the most convenient point, so that the detachable link can be fitted from the back.

The more recent examples of double and treble roller chains—which may conveniently be regarded as equivalent to two or three roller chains side by side—are provided with automatic chain tensioners.

Examination of Timing Chain and Sprocket

When reconditioning a worn engine, the condition of the timing chain and also the chain sprockets should be checked. Assuming that the timing-case cover has been removed, the chain should then be taken off, but before doing so the free portions between the sprockets should be tested for side play; if excessive—assuming there is no jockey or automatic adjuster fitted—this indicates appreciable wear in the chain.

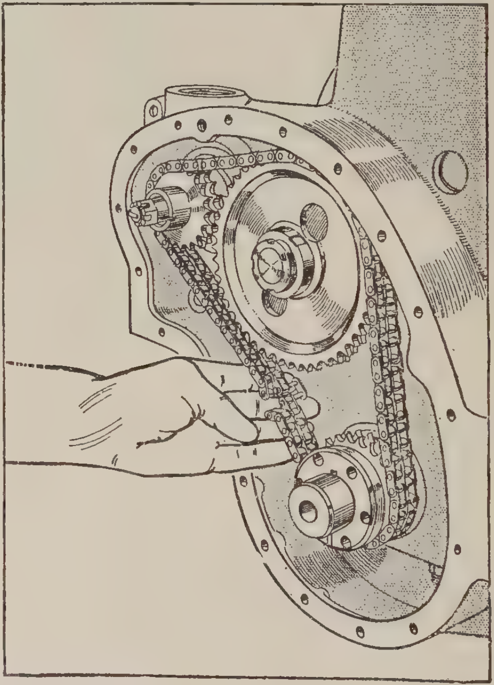


Fig. 255.—Method of Reassembling the Armstrong-Siddeley Timing Chain.

To remove the ordinary roller chain, it should first be cleaned and examined for the spring link. The engine should be turned by hand until the spring link is brought to the most accessible part of the camshaft sprocket. The spring clip will then be found to face the engine side, but there is generally enough room for it to be slid free with a screw-driver. The clip should not be strained in any way during its removal. The rest of the link can then be extracted forwards with the fingers, but—in the case of Austin and similar engines—there is also a loose centre plate, as well as a loose side plate to take out.

When refitting the chain loose link see that the centre plate is properly threaded and also the side plate. The spring link requires little pressure to fit if guided properly into its grooves in the rivet ends.

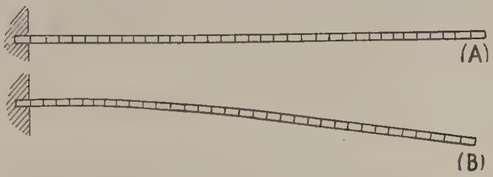


Fig. 256.—Method of testing Roller Chain for wear.

It is essential that the spring clip should " trail "—that is, the open ends of the clip must face away from the direction of rotation. When the link is on the top run of the chain, the open ends should face off-side of the vehicle. The chain runs in a clockwise direction when viewed from the front.

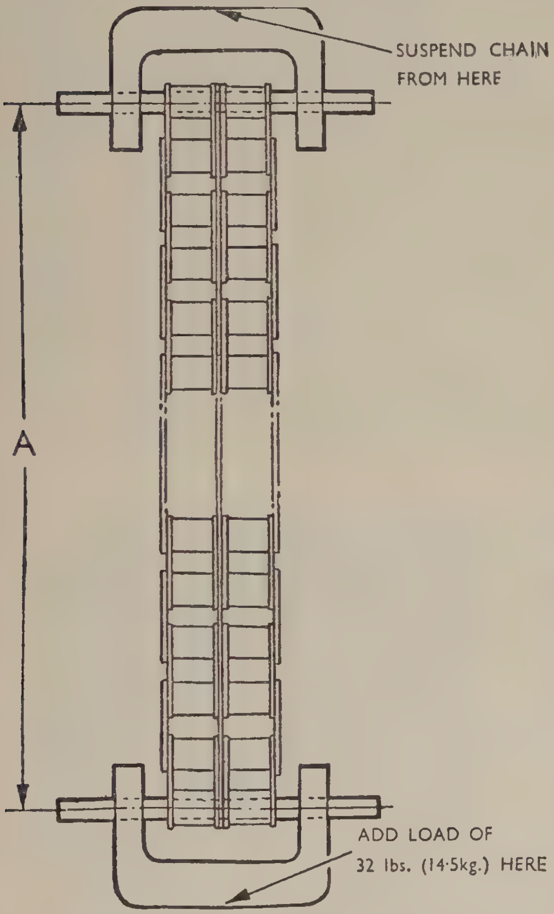


Fig. 257.—Testing for wear in the Vauxhall Engine Chains.

When the timing chain has been removed it may be tested for wear between the side plates by fixing one end in a clamp or vice, and arranging for the chain to lie in the horizontal sense as a cantilever beam. If there is much wear, the chain will assume a downward curve, whereas an unworn chain will remain quite horizontal (Fig. 256).

The method employed in the case of Vauxhall engines for testing the stretch of the timing chain is illustrated in Fig. 257 for the Velox and Wyvern engines. Two V-brackets are used, each drilled and fitted with pins of ·129 in. diameter. The brackets should be attached one at each end of the chain by means of the pins, which should be a snug fit in the brackets and rollers of the chain. One end of the chain is suspended from a suitable fixed point, while at the other end a load of 32 lb. is attached to the bracket. The distance between the centres of the bracket pins should not exceed 18·444 in., but if it does a new chain must be fitted.

Another indication of *both wear and stretch* is the tendency of the chain to *ride towards the tops of the sprocket teeth.* This is due, of course, to the pitch —or distance between the chain links—being greater than the pitch of the teeth on the sprocket wheels; a typical example of this fault is to be found in the case of stretched bicycle chains which ride on the tops of the sprocket teeth. When this occurs in the case of timing chains, they should be renewed.

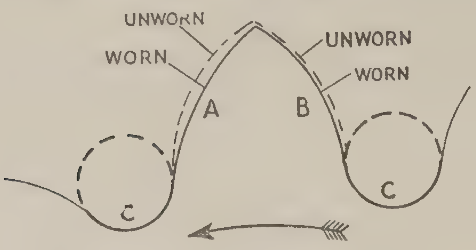


Fig. 258.—Showing how wear occurs on Sprocket Teeth.

Before replacing the new chain on its sprockets the *teeth of the latter should be examined for undue wear.* Such wear occurs mostly on the driving faces of the sprocket teeth, and the result is to cause an alteration to the shapes of the teeth contours. It then becomes necessary to replace the chain sprockets as well as the timing chain.

Referring to Fig. 258, which shows a tooth of a typical sprocket wheel, the driving and trailing sides of the tooth are indicated at A and B respectively. The dotted lines show the profile of the unworn tooth and the full black lines that of the worn tooth. The greater wear occurs on the driving flank A, and there is some wear also on the point of each tooth, so that these points tend to become sharper. Also, in extreme instances of sprocket wear, there may be an appreciable deepening of the troughs, C, of the teeth.

The arrow shown in Fig. 258 indicates the direction of rotation of the driving sprocket of the timing gear.

Automatic Chain Tensioner

In order to obviate the occasional hand adjustment of the timing-chain tension, automatic means are provided in many engines for taking up the slackness.

In one popular method, namely that of the Renolds, a ratchet and pawl device is incorporated in the automatic or adjuster sprocket (Figs. 259 and 260A) so that whilst this idler sprocket can move, under internal spring action, to take up any stretch in the roller chain, the pawls prevent its return in the opposite direction.

The fixed slide is mounted on a bracket that is attached to the timing casing. The idler sprocket rotates on its bearings, and mounting of the latter is provided with the ratchet teeth shown.

When fitting this type of automatic tension adjuster, the roller chain should have a minimum angle of contact of 45°, and the adjuster should slide at right angles to the path of the chain; the amount of straight-line movement is $\frac{7}{8}$ in.

The Coventry adjuster, shown in Fig. 260B, is for a triple roller chain, and it has an eccentric spring-controlled movement about the fixed spindle, part of which is shown on the extreme left and right in Fig. 260B. The components of this type of adjuster as employed in the A.E.C. oil engine are shown in Fig. 261. This adjuster permits of 120° of movement of the chain-wheel centre, located on a ½-in. eccentric throw. The eccentric should rotate *against* the direction of movement of the chain. Both right- and left-hand adjusters are available.

In making major adjustments in the case of the A.E.C. chain, it is necessary to remove the timing case, after having first taken off the radiator. Then remove the sump and block up the front of the engine so that the front support bracket can be removed. Next remove the exhauster and fuel pump. Then "break" the chain at the bottom and remove the nuts securing the timing case to the engine, and lift up the timing case complete with the chain. For "breaking" the chain it is necessary to use a rivet extractor—this is usually provided in the engine's tool kit.

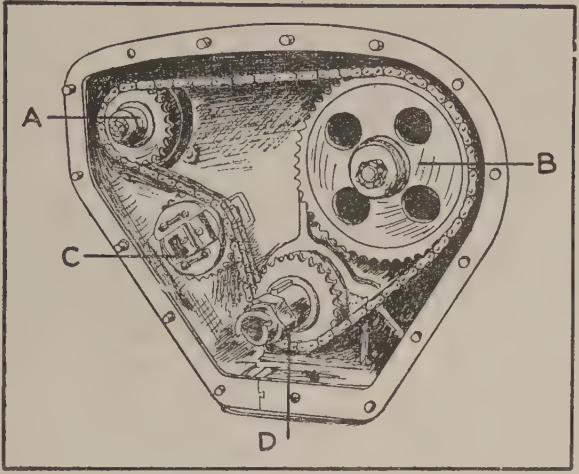


Fig. 259.—Double-roller Chain Timing-gear Drive, with Automatic Tensioner Sprocket.

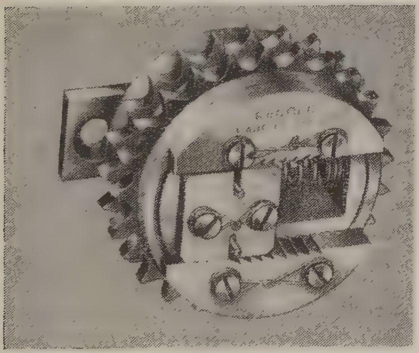


Fig. 260A.—The Renold Double Chain Automatic Adjuster.

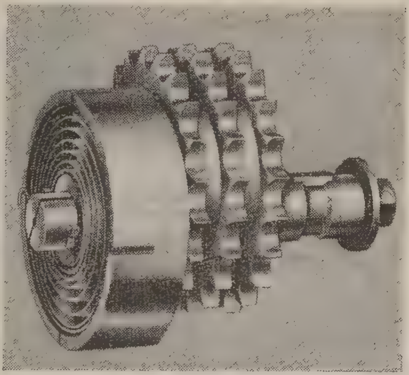


Fig. 260B.—The Coventry Triple Chain Adjuster.

Fitting a New Chain.—When it is required to fit a new chain (after 40,000 to 50,000 miles of service) it is not necessary to remove the timing case. The sump should be removed and the chain tensioner slackened back by releasing the clock spring. The chain should then be broken and *the*

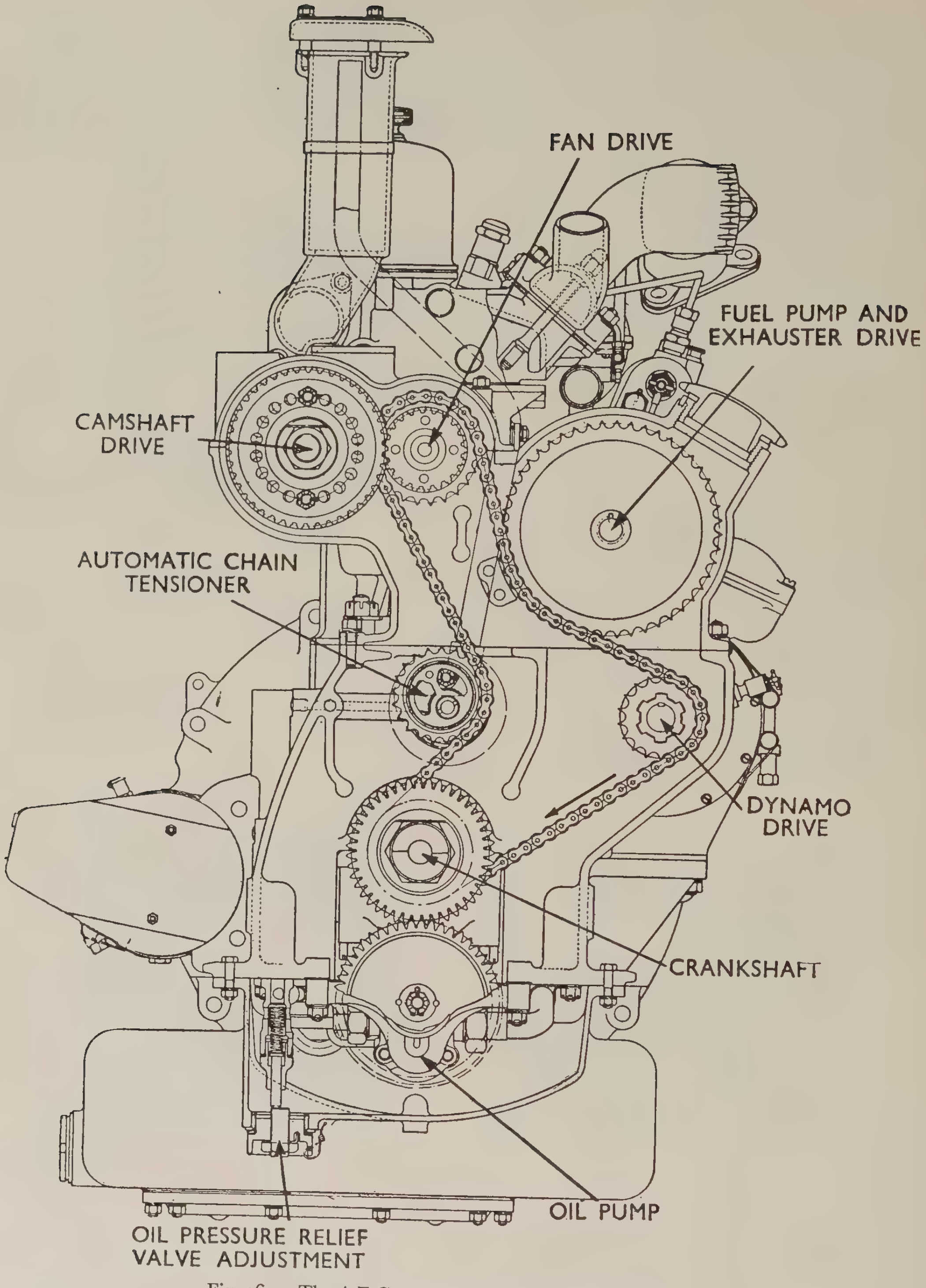

FAN DRIVE
FUEL PUMP AND EXHAUSTER DRIVE
CAMSHAFT DRIVE
AUTOMATIC CHAIN TENSIONER
DYNAMO DRIVE
CRANKSHAFT
OIL PUMP
OIL PRESSURE RELIEF VALVE ADJUSTMENT

Fig. 261.—The A.E.C. 7·7-litre Oil Engine Timing Gear

new chain attached to one end of it by means of a link. The crankshaft should now be rotated so that the new chain is fed on to the sprockets as the old one is removed. When it is completely fed on, the new chain should be riveted up and the chain tensioner adjusted.

Replacing a Timing Chain

To replace the timing chain when reassembling the timing case on the engine, remove the oil filler from the timing case but leave the chain-tensioner sprocket hanging loosely on its spindle. Feed the chain into the timing case so that it wraps over the fan sprocket at the top and down on the underside of the exhauster and fuel-pump sprocket. Leave about an equal length of chain hanging down below the timing case on either side and lower the timing case on to the crankcase so that the chain drops between the camshaft sprocket and the crankcase wall on the off-side, and over the dynamo sprocket and over the chain-tensioner sprocket on the near-side. Lower the timing case on to the crankcase and fix down with nuts. Then from the underside of the engine feed the off-side end of the chain from the camshaft sprocket over the top of the crankshaft sprocket

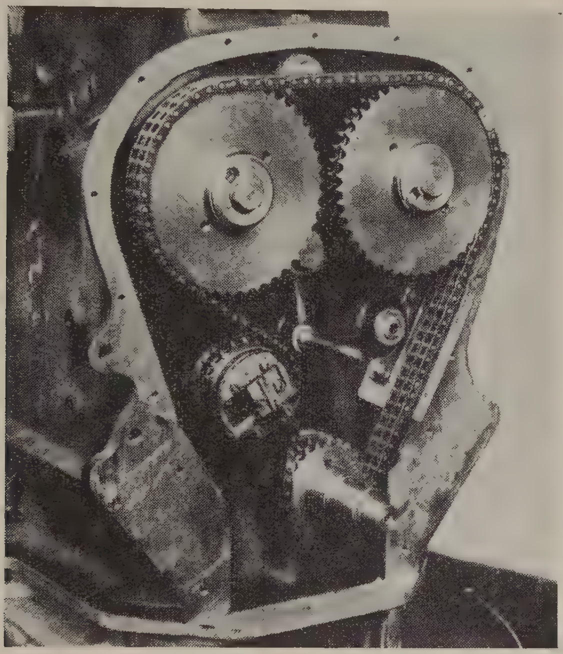


Fig. 262.—Typical Example of Ratchet-type Chain Tensioner on the Riley 2½-litre Engine. The Renolds Duplex Roller Chain of ⅜-in. Pitch is used. The Number of Teeth on the Crankshaft and Camshaft Sprockets are 23 and 46 respectively.

and join up to the other end with the slack end of the chain embracing the idler sprocket. Now fit the eccentric into the chain-tensioner sprocket

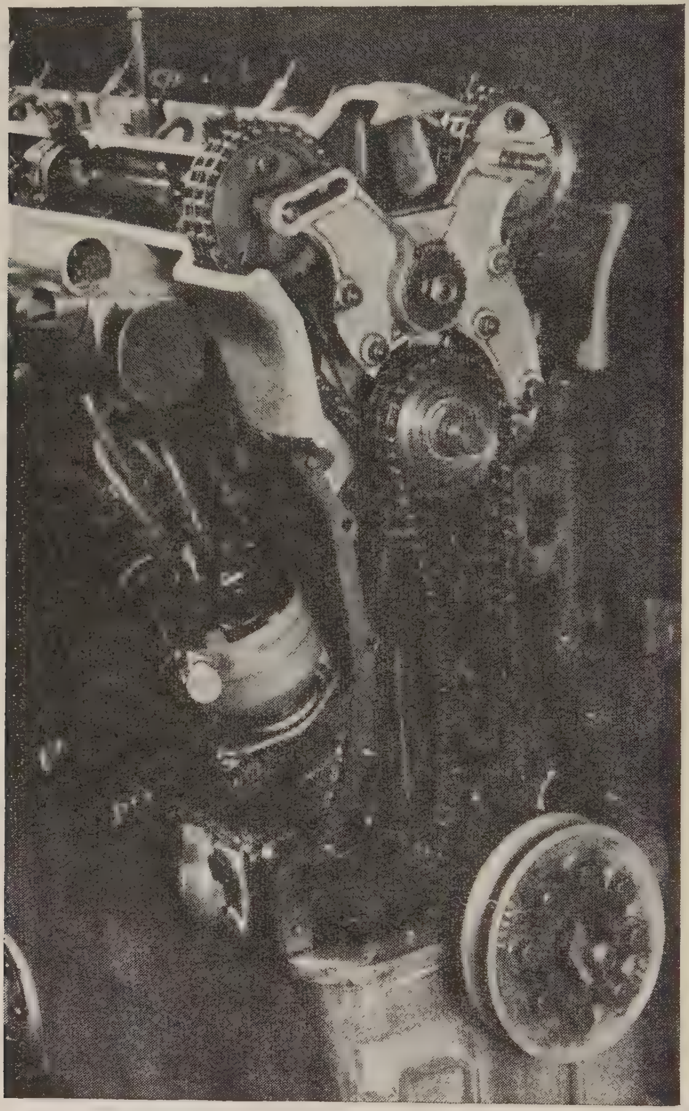


Fig. 263.—Chain Drive of Jaguar XK120 6-cylinder Engine—Renolds Roller Duplex Chain of $\frac{3}{8}$-in. pitch. First stage: Crankshaft Sprocket, 21 teeth, to Intermediate Sprocket, 28 teeth. Spring-blade Tensioner. Second stage: Intermediate Driving Sprocket, 20 teeth. Camshaft Sprockets, 30 teeth. Jockey Sprocket, 21 teeth.

and turn the eccentric in an anti-clockwise direction as far as it will go and replace the ratchet. It is, of course, necessary to retime the engine when the chain has been removed.

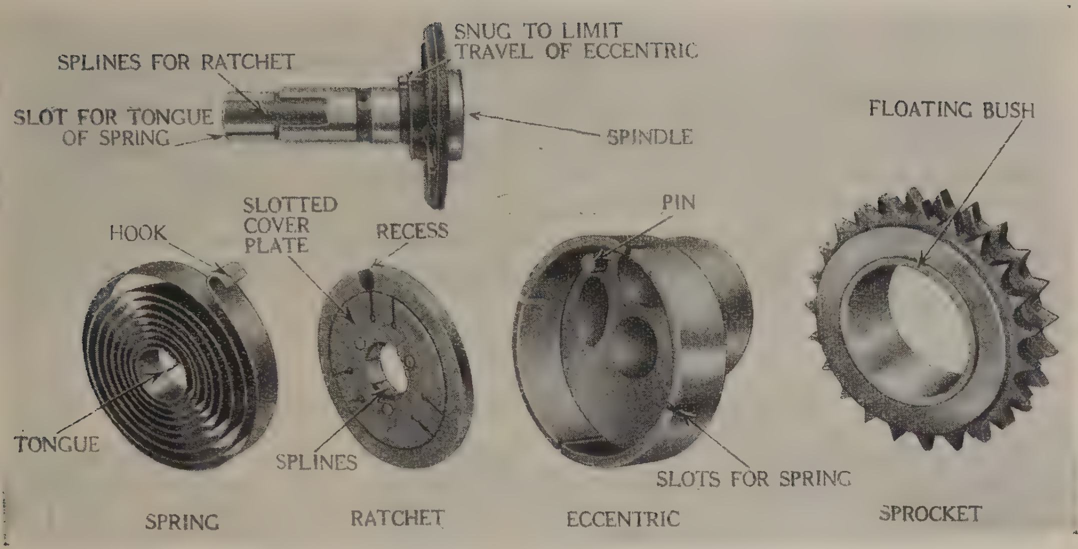


Fig. 264.—Components of A.E.C. Automatic Chain Tensioner.

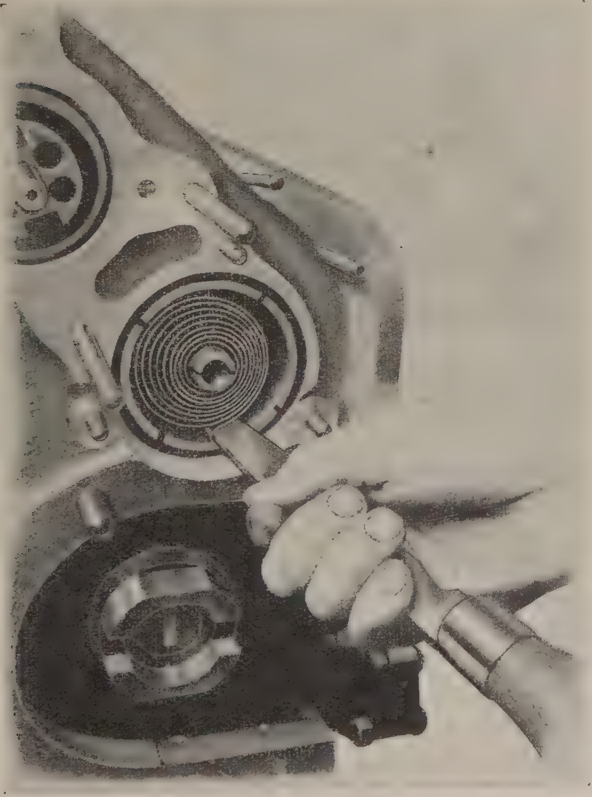


Fig. 265.—Adjusting A.E.C. Automatic Chain Tensioner.

To Tension the Chain Correctly

Turn the chain-tensioner eccentric as far as it will go in an anti-clockwise direction, replace the ratchet with its slotted cover plate outwards, and engage the pin in the eccentric with the slot in the ratchet. Engage the tongue in the centre of the spring with the slot in the chain-tensioner spindle and *wind up three and a quarter turns* in a clockwise direction. Then lock the end into one of the four slots provided for it in the outer edge of the eccentric (Figs. 264 and 265).

The Camshaft and its Bearings

The camshaft, which runs at one-half engine speed, is usually carried in four bearings which in modern engines are of the white-metal shell pattern. In some cases three of the bearings are of the shell type and the fourth or rearward one is a plain bearing in the cylinder-block casting.

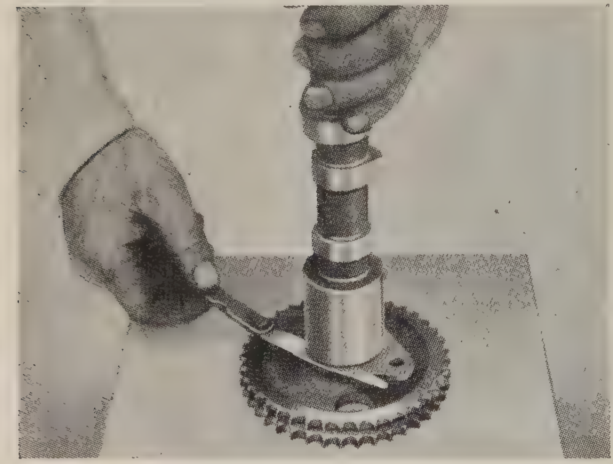


Fig. 266.—Checking the Bedford Engine Camshaft End Clearance with Feeler Gauge. This should be from ·002 in. to ·004 in.

The camshaft is generally located by a thrust plate held to the cylinder block by three setscrews with lock washers. There is always a small amount of clearance, namely ·002–·006 in. between this locating plate and the boss on the camshaft gear.

In all instances the camshaft can be withdrawn through its bearings once the location plate and the timing cover have been removed. Care must be exercised when taking the camshaft out that the sharp edges of the bearing journals and cams do not damage the soft white-metal of the bearings.

The bearings seldom require attention, as they are lightly loaded and copiously lubricated and will outlast the crankshaft bearings by a big margin. When the engine is being given a major overhaul, it is as well. however, to *check the wear between the camshaft and its bearings* and also to *examine the wearing faces of the cams.* If the camshaft is not to be taken out of the cylinder block, *the end play or float* should be *checked with a feeler gauge.* If excessive, it should be reduced by the method of adjustment provided, e.g. by end screw and plate or shims. The method of checking the camshaft thrust-plate clearance in the case of the Bedford engines is illustrated in

Fig. 266; it will be observed that this checking can usually be done with the camshaft removed or in position.

Removal of Camshaft without taking out the Valves

It is possible in some designs of engine to take out the camshaft without removing the valves, springs, and tappets. As an example, the Chrysler side-valve engine will be considered. Having removed the timing-gear cover camshaft sprocket (with pulley withdrawal tool) and timing chain, the valves are all raised and then held in place by inserting two wooden wedges under each valve head (Fig. 268) at opposite points to prevent the stems from distortion. Next the valve tappets are lifted one by one and held up hard against the valve stems with the aid of wooden clothes-peg clips. The tappets now being clear of the cams, the camshaft can be pushed out. It should be rotated as it is withdrawn so that the journals and cams will clear the bearings. Having taken out the camshaft, the thrust plate and collar should be withdrawn in an arbor press.

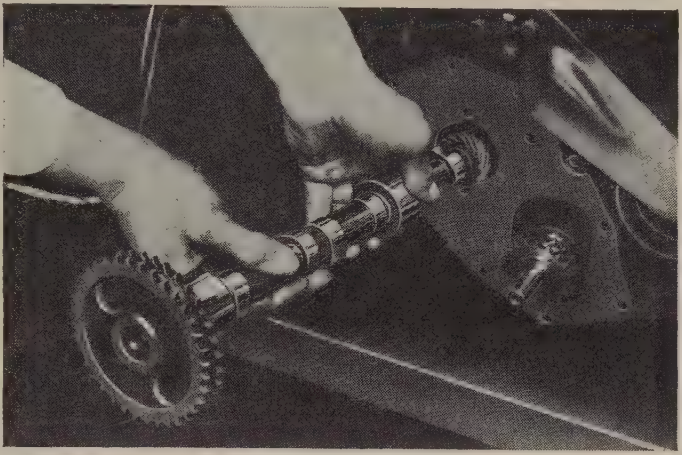


Fig. 267.—Removing the Vauxhall Velox Camshaft, complete with Sprocket.

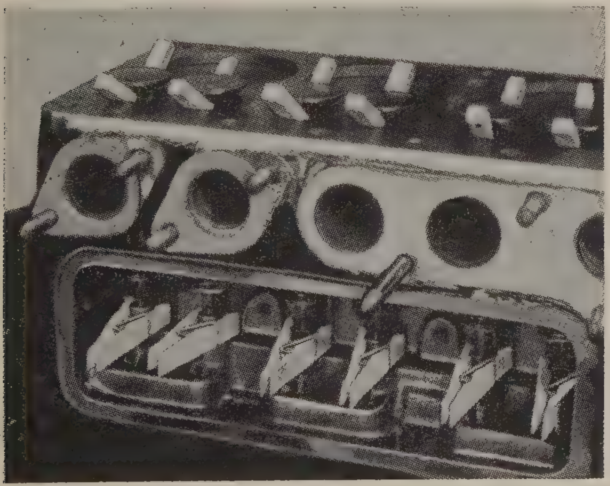


Fig. 268.—Removing Camshaft without taking out the Valves.

If the camshaft bearings have worn they should be knocked out with a rod having a shouldered end. Replacement bearings are finished to such close limits that they do not require reaming or scraping. In this case the *bearing clearance* is ·0015–·0035 in., and the *end play* is ·002–·006 in. These values represent standard practice in most British and American cars.

Examination of the Cams

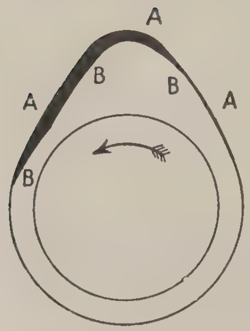


Fig. 269.—Worn Cam.

When an engine that has been in service over a long period is to be completely reconditioned, the camshaft should be checked for wear on (1) the bearing journals, (2) the cam faces. Generally, there is very little journal wear, but the cams may be found to have worn on the valve-lifting faces, as indicated to exaggerated scale in Fig. 269. The outer line AAA denotes the unworn and the inner line BBB the cam's worn profile. A high degree of polish and sharp edges on the cam are the usual indications of wear regions, but unless an unworn camshaft is available for comparison it is difficult to assess the amount of wear other than by inspection of the symmetry or otherwise of the lifting and closing faces of the cam. Apart from normal wear, the cam faces may be found to be scored or pitted; in this case a new camshaft is the only satisfactory remedy.

Fig. 270 illustrates one of the cam profiles of a Leyland oil engine, namely the 9·8-litre model. The amount of wear on the cam is tested by measuring the distance between the nose and back of the cam. When new this distance should be 1·995–2·005 in. When this distance is reduced by wear to 1·983 in., corresponding to ·012–·022 in. of wear, the camshaft requires renewal.

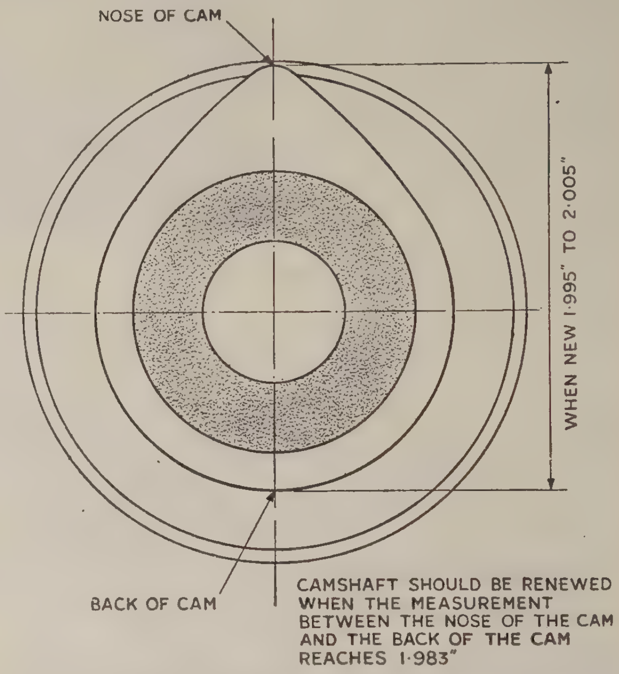
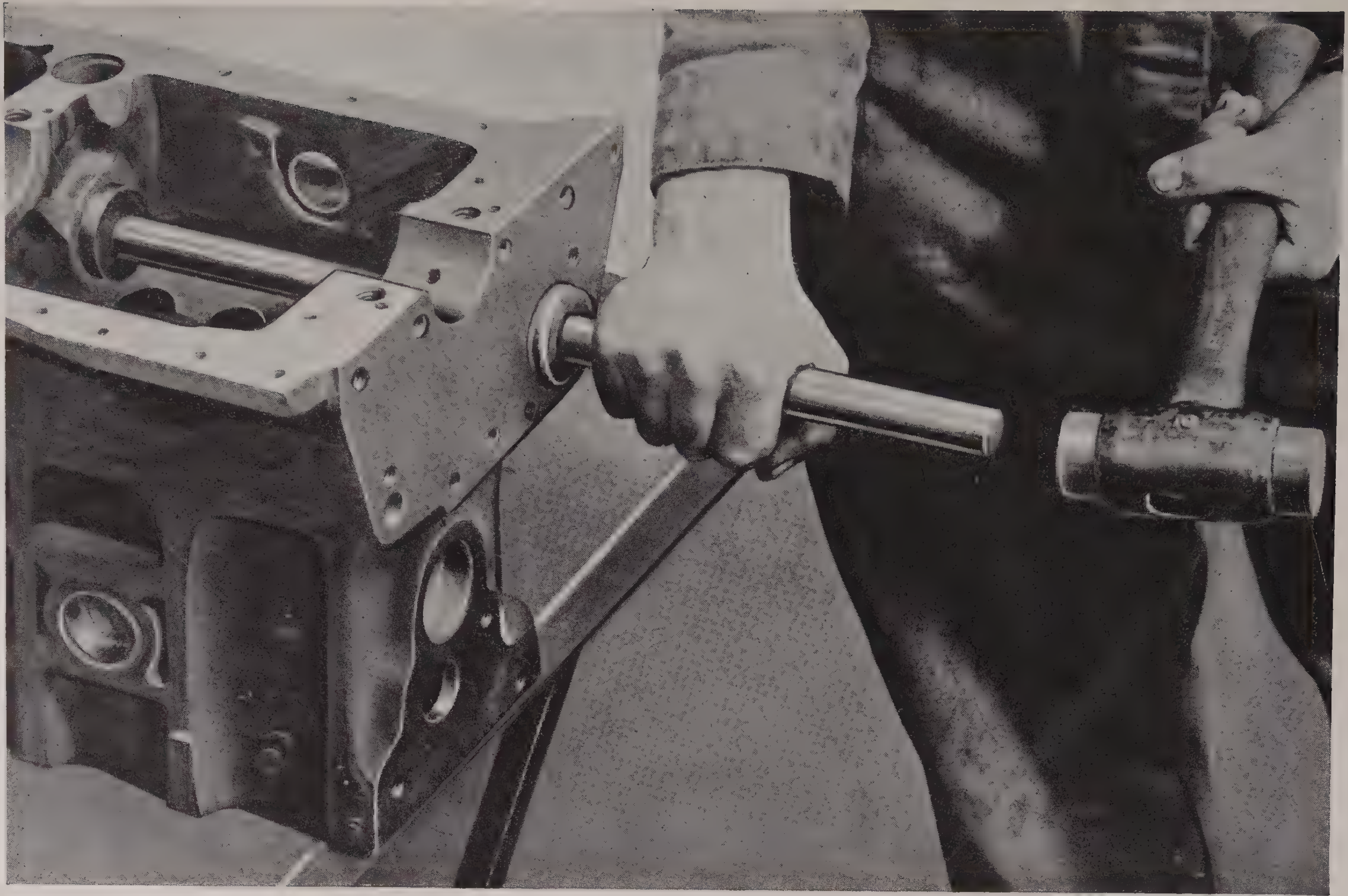

NOSE OF CAM
WHEN NEW 1·995" TO 2·005"
BACK OF CAM
CAMSHAFT SHOULD BE RENEWED WHEN THE MEASUREMENT BETWEEN THE NOSE OF THE CAM AND THE BACK OF THE CAM REACHES 1·983"

Fig. 270.—The Leyland 9·8-litre Oil-engine Cam Profile.

Replacing Camshaft and Bearings

The timing-chain sprocket (or gear) must be replaced on the camshaft and boss, using a press for this purpose. If renewed, the bearings in the engine block should be checked for bearing clearance. In some cases, after the white-metal shell bearings have been replaced it is necessary to see that the oil-holes register with those in the bearing housings, and it may also be necessary to reamer the bearings in line to give the correct clearance value.



REMOVING THE FRONT INTERMEDIATE CAMSHAFT BEARING ON BEDFORD MODELS K, M AND O 28-H.P. SIX-CYLINDER ENGINES, FOR BEARING RENEWAL PURPOSES.

CHAPTER 8

THE PISTON RINGS

After an engine has been in use for an appreciable period, it will be found that not only have the piston rings lost a good deal of their spring, but owing to wear the gap will have opened sufficiently to allow the exploding and expanding gases to leak past the piston; on the suction and compression strokes also there will be leakage of gas.

Not only this, but the oil from the crankcase will also find its way past the piston and will burn in the cylinder head, thus causing more rapid carbonising. In general, then, the engine will run less efficiently, will lose power, will require decarbonising more often, and, finally, will show a greater petrol and oil consumption.

The piston itself may, of course, be partly responsible, for if it is worn to any appreciable extent, it will tend to exhibit the same bad effects as the worn rings; as, however, the piston rings are fitted primarily for the purpose of rendering the piston gas-tight, they are usually the first and worst offenders.

After the piston rings have been removed from their piston grooves—and labelled so that if replaced they go back into their proper grooves—they should first be tried in the cylinder by themselves, and the gap measured with a feeler gauge. If the *piston-ring gap* is found to be greater than ·02 to ·03 in., the ring should be discarded. The width of the piston ring is also an important factor, and this should therefore be measured with a micrometer; the groove clearance should not exceed ·002 in.

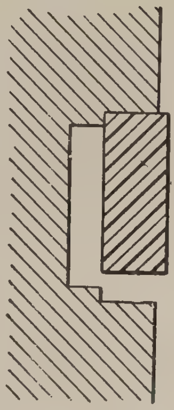


Fig. 271.—Illustrating how a Piston Ring wears the Slot.

Sometimes it will be found that, owing to the piston ring having been originally fitted with too much clearance in its groove, the latter is hammered, as it were, into the profile shown in Fig. 271, so that the piston groove is distorted; a close examination of a piston which has been in use for some considerable time will sometimes reveal this ridging effect. The only remedy, if the piston clearance is still within the allowable limits, is to put the piston in a lathe, and to turn out the ridges, taking care to remove as little material as possible. New piston rings should afterwards be fitted.

Stock Piston Rings

When the question of fitting new piston rings arises, it should be remembered that there are specialist firms of piston-ring manufacturers, for example the British Piston Ring Co., Ltd., Coventry, and the Light Production Co., Ltd., London, who make and stock a very large variety of piston rings. It is well worth while before proceeding to make one's own piston rings to inquire first from the makers of the automobile, or, failing a satisfactory reply, from piston-ring specialists (who, it may be added, usually supply the car manufacturers).

The well-made stock piston rings are finished to very fine limits by the grinding process on the parallel faces and external diameter; the face limits are usually one-quarter of a thousandth inch, and the cylindrical surface limits about the same. Apart from accuracy of measurement, the rings are so designed, or rather treated by a special hammering or repeated grinding process, that when inserted in the cylinder for which they have been designed, they will exert a uniform pressure outwards all round. This is an important matter, for if the ring pressure is not uniform —and it certainly is not in the case of a "plain turned and cut" ring— the ring will wear more rapidly and unevenly.

The usual stock sizes in metric measure of the leading piston-ring manufacturers range from 50 mm. to 250 mm. The corresponding widths are from 3 or 4 mm. to 10 mm. The diameters usually increase by 1 mm. up to about the 130-mm. size, and thence in 5-mm. steps to 250 mm. There are many ring sizes to $\frac{1}{2}$-mm. diameters, e.g. 50$\frac{1}{2}$ mm., 55$\frac{1}{2}$ mm., 60$\frac{1}{2}$ mm., etc. Further, it is possible to obtain other special sizes and also *two-stroke engine* rings with a special joint.

The English stock sizes range from 2 in. × $\frac{5}{32}$ in. to 30 in. × $\frac{3}{4}$ in., increasing usually by quarter-inches. Odd sizes, in $\frac{1}{10}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$ and decimal units, are also stocked.

Further, *special oversize rings* are stocked, which are particularly suitable for engines in which the cylinders are slightly worn. Thus, in the case of a certain engine originally fitted with piston rings of 3 in. × $\frac{13}{16}$ in., the piston-ring stockists[1] supply the following sizes:

3 in. + ·010 in. × $\frac{3}{16}$ in., 3 in. + ·020 in. × $\frac{3}{16}$ in. and 3 in. + ·031 in. × $\frac{3}{16}$ in.

Numerous other examples of oversize rings for worn engines are to be found in the published lists of such firms. It is fairly safe to state that in most cases stock piston rings are obtainable for replacement purposes.

Types of Piston Rings

There are two principal types of simple piston ring, namely the "*concentric*" and the "*eccentric*" kinds. Each has its merits, but whereas the former type is now the most widely used, the latter is only to be found on a few earlier engines still in service.

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[1] The British Piston Ring Co., Ltd., Holbrooks Lane, Coventry.

The concentric type, as its name implies, is of equal thickness, and therefore fits evenly in the piston-ring groove. It is, however, a little more difficult to manufacture so as to give a uniform bearing pressure when placed in the cylinder. If a plain concentric ring be turned in a good-grade cast iron and then sawn diagonally so that when closed it fits in the cylinder, it will not be truly circular in shape, but oval; moreover, the ring will only bear on the cylinder walls at the places indicated by the letters A (Fig. 272). There will therefore be a leakage of gases past the rings at B (Fig. 272), and, further, the ring will wear unevenly, the greatest wear occurring near the gap.

If, however, the piston-ring blank be turned slightly larger in diameter than the cylinder—namely, by a few thousandths of an inch—and then a slot of about $\frac{3}{32}$ to $\frac{5}{32}$ in. be cut (in the case of a 3-in. ring), the ring when closed will *not* as previously stated fit the cylinder, but will assume an oval shape, the smaller diameter of which is a little greater than that of the cylinder; this smaller diameter occurs at right angles to the diameter through the slot.

If, now, the ring be clamped between two discs or plates with the gap closed, and the external surface exposed so that it can be turned or, better still, ground, and the ring be turned or ground until it is about ·001 to ·0015 in. smaller in diameter than the cylinder, it will not only fit the cylinder evenly all along its surface, but, what is more important, will give a practically uniform pressure all around the cylinder wall in contact with it. This property can be shown experimentally, and can also be proved mathematically; the late Professor John Perry, M.I.M.E., first demonstrated this method of obtaining a true and uniform-pressure piston ring.

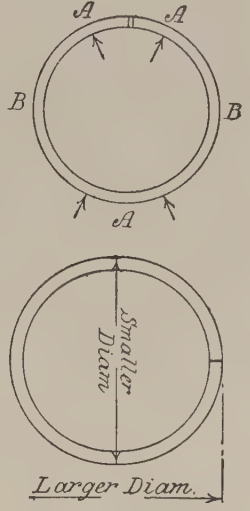

Fig. 272.—The Plain Turned and Cut Ring.

Another method, which is now almost universally employed in the commercial manufacture of piston rings, consists in first turning and parting the concentric ring in the usual manner, and then slitting it at 45°. The slit ring is then subjected to a *process of hammering* on the inside surface and in a radial direction, the object being to equalise the resilience or spring property at all parts of the ring. The intensity of each hammer blow is graduated for this reason, the blows being lightest near the gap and more severe at the place opposite the gap. Hammered rings can readily be detected by the small "chisel-like" marks inside them (Fig. 273). This type of piston ring gives very good results in practice.

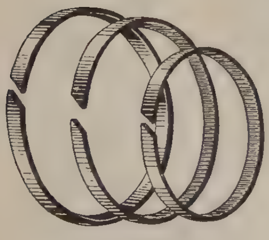

Fig. 273.—Hammered Piston Rings.

It is necessary, after the hammering operation, to surface grind the faces of the ring, so as to take out any irregularities caused by the hammering process.

There is *a third method* which is occasionally employed in making piston rings of the concentric type, and is often resorted to in small garages and works when making special sizes of rings. It consists in first turning a concentric ring of the usual type, and slitting it at 45°, so that when the ring is closed it can just be inserted in the cylinder; it is then lapped in with fine emery and oil. It is better to lap the rings in on a dummy piston and in a slightly larger diameter dummy cylinder, as the actual piston and cylinder may wear slightly in the lapping operation. If a number of rings—say, a set of eight or twelve for an engine—has to be made, it will repay the extra trouble to lap them in in a dummy cylinder, rather than risk increasing the clearance between the real cylinder and piston. Although the rings thus made are quite circular, and give a roughly uniform pressure, the method is inferior to the other two, and it is not easy to ensure the correct final dimension, or gap clearance. It can, therefore, only be regarded as a makeshift method.

The eccentric-pattern piston ring, if properly designed, gives a more uniform pressure than the plain non-hammered split concentric type, but it requires careful proportioning. In most cases, for practical reasons, it is made thicker at the slotted end than theoretical considerations require, and it wears more at these places; it should wear evenly, if well designed. The eccentric ring, being thicker at the place opposite the gap, requires a rather deeper piston-ring groove. It is heavier than the concentric type; this is a drawback in these days of very light high-speed engines, where it is essential to keep the weight of the moving parts, e.g. the pistons and connecting rods, down to a minimum. There is a further objection to eccentric rings, namely, that owing to the greater clearance between the small ends (or gap portion of the ring) and the piston-ring groove inner surface, the oil tends to collect and to carbonise here, ultimately filling the space. The gases also tend to leak past the thin ends of the piston rings more than in the case of the concentric type.

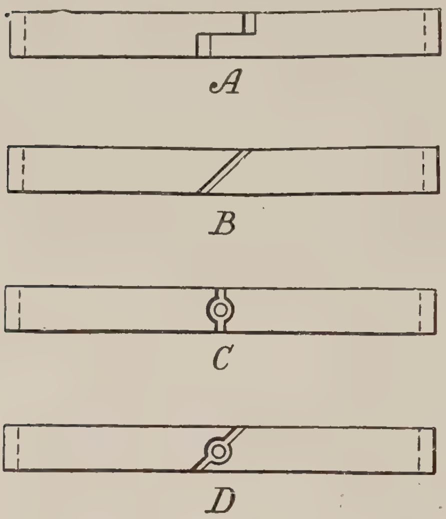

Fig. 274.—Types of Piston Ring.
A, Stepped. B, 45° Slit. C and D, Pegged Rings for Two-stroke Engines.

The hammered or doubly-ground concentric rings are therefore the best types of piston rings.

As regards the *type of slit*, many manufacturers prefer the 45° *slit* (Fig. 274, B), as it simplifies the process of making the rings. The *stepped ring* (Fig. 274, A), however, although a little more expensive to manufacture, allows the ring to expand and to wear without increasing the gap as in the preceding case. It does not however give any better gas-tightness than the diagonal-cut ring.

In the *case of two-stroke engines*, of the two- or three-port type, it is necessary to provide wider rings, as a rule, and to peg these in the piston grooves, so that they will not turn and foul the cylinder ports. It is usual to arrange a peg between the two ends, whether plain or diagonal cut (Fig. 274, C and D).

Typical Piston-ring Set

A typical arrangement of piston rings for a three-slot piston is illustrated in Fig. 275. It consists of an upper hammered flexible compression ring, A, an intermediate piston slot flexible ring, B, which conforms to the shape of the cylinder, even if worn, and a lower oil control or scraper ring, C, to minimise oil consumption whilst maintaining proper lubrication of the piston and cylinder surfaces. The second slot ring acts partly as a compression and partly as an oil-control ring. The complete assembly, which is made by American Hammered Piston Rings Co., gives a very good combination for gas-tightness, good wall lubrication, and low oil consumption.

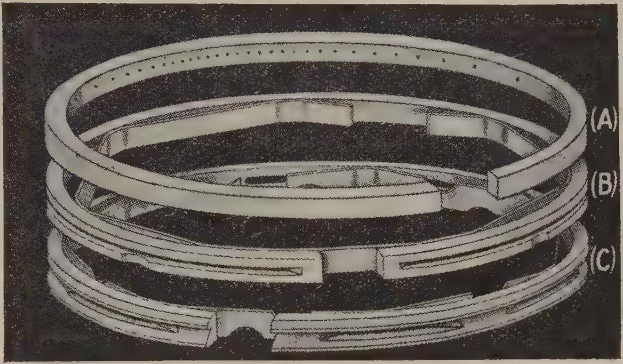

Fig. 275.—Typical Piston-ring Set for gas-tightness and oil control.

Compound Rings

Apart from the simple forms of piston ring described, there is a number of more complicated designs of piston ring on the market, the general object of each being to provide a more gas-tight joint and more uniform pressure. Most designs aim at providing a very long leakage path for the gases.

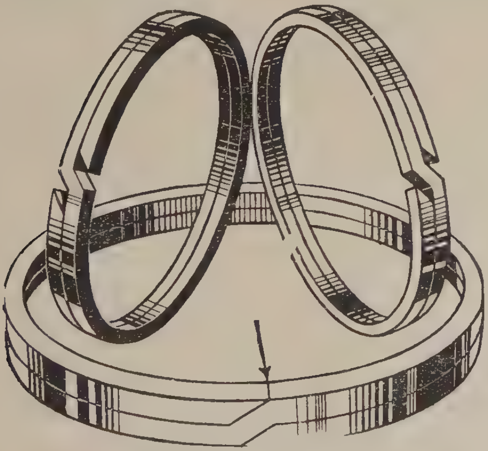

Fig. 276.—The Clupet Piston Ring.

The simplest form of compound ring is that made by employing two identical single rings of half-width in the same piston groove. The slots are placed at 180° apart. This type has been used on aircraft, motor-cycle, and car engines. The only trouble experienced is that of the slots working into line.

Another type of ring consists of an outer single ring and an inner ring which presses against the inside surface ; the two slots, as before, are at 180° apart. This gives a more uniform pressure, but does not reduce leakage appreciably. The Clupet ring shown in Fig. 276 is used for replacement purposes; it consists of a single-piece ring having a long leakage path.

The general feeling amongst automobile engineers is that in long service the compound ring, having more surfaces and parts, is apt to carbonise or gum up more readily, and that the well-designed and constructed single ring gives satisfaction in most cases. Moreover, it is lighter in weight and less expensive ; it can easily be replaced.

In the case of many worn engines, however, the compound ring often offers a solution, or at least a partial one, to the oil and gas leakage past the piston, and for replacement purposes this type is, therefore, used to some extent.

Special Replacement Piston Rings

In the case of engines which have not covered a sufficient mileage to necessitate the reboring of the cylinders and in instances where the reboring is not at the time convenient, for various reasons, the engine can be given a new lease of life by fitting special replacement piston rings in the lower groove or two lower grooves.

These special rings may be regarded as combination compression and oil scraper rings, which not only tend to give a better compression in worn cylinders but also reduce the oil consumption to a marked extent.

The principle of the modern replacement ring is that of a plain flexible alloy cast-iron ring having a spring-steel expander inside it, i.e. between the back of the ring and the bottom of the ring slot in the piston. This expander bears on the ring at several places and, owing to the flexible design and material of the ring, enables the latter to conform to the worn contour or shape of the cylinder barrel.

The Wellworthy Simplex and Molium rings and the Muskegon ring are examples of this type of double piston-ring unit.

Fitting Simplex Rings

Referring to Fig. 277 which illustrates the Simplex ring, this consists of an inert or “ dead ” cast-iron ring provided with a series of peripheral narrow slits and separate inner spring-steel ring bearing at about seven places on the cast-iron ring. The object of providing the peripheral slits is to give side flexibility so that the ring can be slightly compressed sideways to enter the piston-ring slots and thereby fill the latter, whilst still retaining its flexibility, thus preventing oil and gas leakage behind the ring from one side of the piston-ring slot to the other. It is claimed that this ring will compensate for uneven cylinder wear up to ·015 in. and will adapt itself to out-of-roundness and taper of the cylinder barrel, whilst eliminating piston slap.

The Simplex ring should be fitted in the middle groove in the case of a three-ring piston, i.e. immediately above the scraper ring.

In all cases where expander rings are fitted, the top ring should be a plain compression-type one.

The piston-ring groove should be machined to the same width as the Simplex ring. The depth of the ring groove must be made to the value recommended by the manufacturers so as to take the spring ring. It should be accurate to within plus or minus ·002 in. Special depth gauges can be obtained for checking the ring-groove depth. When possible, ring-groove drainage should be provided at the back of the ring by drilling small holes through the bottom of the groove to the inside of the piston.

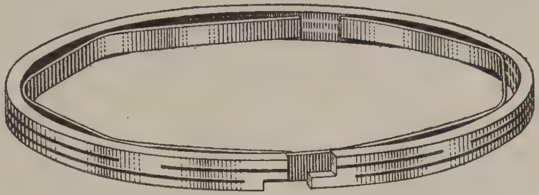
Fig. 277.—The Simplex Piston Ring.

A typical Simplex ring suitable for cylinders of $2\frac{1}{2}$-in. to 3-in. bore has a depth of groove of $\frac{1}{8}$ in. and width of relief of $\frac{5}{32}$ in.; about 8 holes of $\frac{1}{8}$-in. diameter are suggested for oil drainage. The solid portion of the step in the gap portion should be at the bottom. The gap in the expander ring must be opposite the gap in the outer cast-iron ring; the gap in the latter should be in line with the gudgeon-pin axis and evenly supported by one of the " humps " of the expander (Fig. 277).

In the case of worn piston-ring grooves these should be machined " square " and to suit the dimensions of the selected Simplex ring.

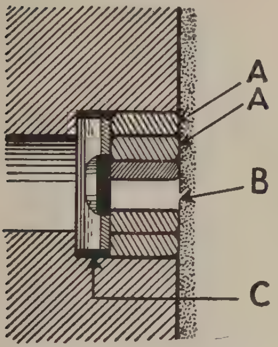

Fig. 278.—The Duaflex Piston Ring.

Other Types of Replacement Ring

A more recent replacement ring, by the same manufacturers,[1] known as the Duaflex, has given notable results in worn cylinders in regard to reduced oil consumption and improved power results. The principle employed is to use four rounded-edge flat sections, A (Fig. 278), made of a special alloy steel. Two of these rings, A, are at the top, and two at the bottom of the ring groove. Between the two pairs of these rings is placed a centre spring B, in the form of a crimped or wavy expander which forces the flat-section rings against the piston-slot faces. In addition, there is an inner polygonal spring ring C, similar to that used in the Simplex ring previously described, for pressing the flat-section rings outwards against the cylinder wall.

The rings conform to the shape of the wall, even if oval or badly tapered. The cushioning effect of the expander reduces piston slap to a minimum.

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[1] Wellworthy Piston Rings, Ltd., Lymington, Hants.

The waved spring between the flat rings provides ample oil drainage and prevents oil pumping. The rounded ends of the flat rings reduce friction and improve the compression, but they have no oil-scraping action. Whilst four of these flat rings are shown in Fig. 278, the number can be varied to suit the width of the piston groove. Tests on various worn engines have revealed striking results with these piston rings.

The Molium, ring consists of several thin rings made of a special alloy known as Molium, which is a flexible low-friction metal softer than the cylinder walls. As in the Simplex ring there is an inside spring-steel expander ring so that the outer multiple ring adapts itself to oval and tapered cylinders. Owing to the multiple edges of the component rings oil-pumping action is prevented and a number of friction-reducing oil seals are provided.

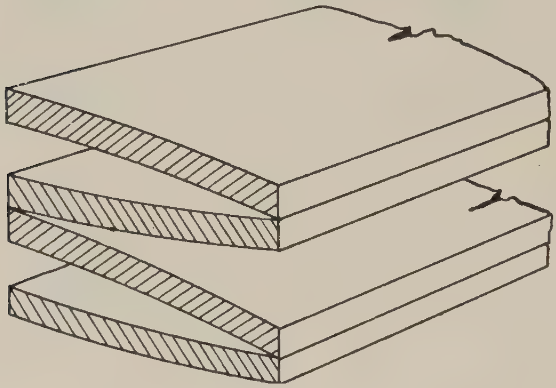
Fig. 279.—The Cords Piston-ring Assembly.

Molium rings should be fitted in the second (from the top) and third ring grooves; a plain compression ring should be used in the top groove.

The Cords piston ring (Fig. 279) is also a composite one built up of a suitable number of separate arch-section thin spring rings of special low-friction alloy. Each ring has a plain radial slot. Owing to the arch or cup section the rear ends bear against the ring-groove walls and prevent gas leakage. The multiple scraping edges (which are rounded off) prevent oil pumping. In the case of a three-ring piston of 3 in. diameter the recommended plan is a plain compression ring in the top groove; a 3-unit Cords ring in the middle groove and a 5-unit Cords ring in the bottom groove. The end gaps when in the cylinder should not be less than ·01 in. Each component arched-ring occupies exactly $\frac{1}{32}$ in. of piston-ring groove, so that from this the appropriate number of rings can be chosen to suit the machined piston-ring groove. All grooves, it will be seen, must be of width equal to a multiple of $\frac{1}{32}$ in.

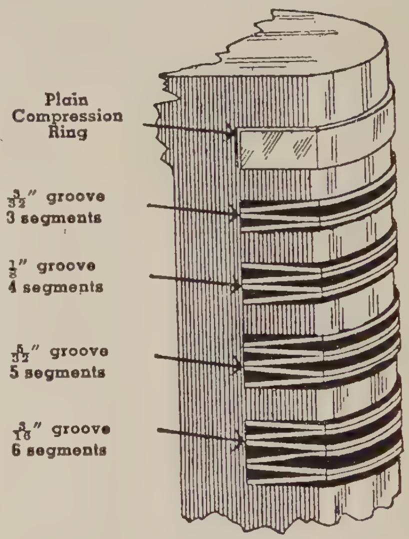
Plain Compression Ring
$\frac{3}{32}$" groove 3 segments
$\frac{1}{8}$" groove 4 segments
$\frac{5}{32}$" groove 5 segments
$\frac{3}{16}$" groove 6 segments
Fig. 280.—Alternative Arrangements of Cords Piston Rings.

Fig. 280 illustrates the various ring arrangements in the case of a five-groove piston.

The Trancosteel replacement ring is similar in principle to the Cords ring but has straight inclined component rings instead of arched ones.

Tapered Piston Rings

These wedge-shaped or tapered rings, fitted in piston grooves of corresponding taper, have an angle of 10° between the tapered sides. They operate at a lower temperature, are not prone to sticking or gumming up in the piston-ring grooves, do not experience ring "flutter," and in general provide a better gas seal than plain rectangular-section rings. When the ring is pushed down to the bottom of its groove the side clearance should be ·001 to ·002 in. These rings are particularly suited to the requirements of large commercial petrol and Diesel engines.

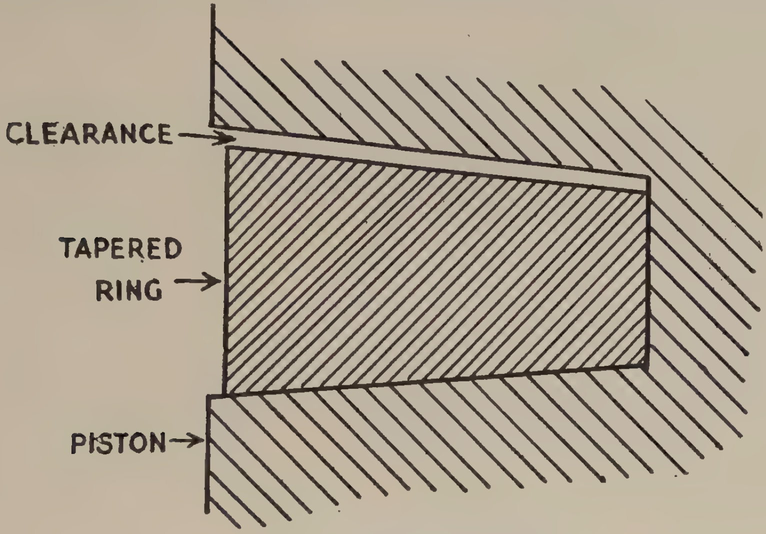

Fig. 281.—Tapered Piston Ring.

Chromium-plated Piston Rings

Piston rings are now available with chromium-plated surfaces, using a porous chromium deposit on the outer surface. It has been proved that with such rings both cylinder wear and piston-ring wear are reduced appreciably, whilst the porous nature of the chromium improves the lubricating properties of the ring and reduces cylinder-wall friction.

A modern piston ring of the chromium-plated type that has given very good results in regard to prolonged resistance to wear is shown in Fig. 282. The ring has a deposit or layer of chromium of thickness X, equal to

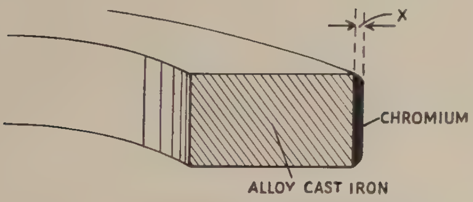

Fig. 282.—Chromium-plated Piston Ring.

·002–·003 in., and the upper and lower edges are rounded in order to reduce wall friction and minimise oil pumping. In another ring of this general design the region denoted in black by the thickness *X* is made up of an outer layer of ·001–·002 in. of porous chromium and an inner layer of ·002 in. of hard solid chromium. The porous layer much improves the lubrication qualities of the ring as compared with the solid metal.

Making Piston Rings

It is not within the present considerations to go into the technicalities of piston-ring manufacture or design, as this is a specialised branch of engineering outside the scope of this work.

To those desirous of knowing the standard dimensions and specifications of piston rings, we would refer to the *Specifications of Piston Rings*, published by the British Engineering Standards Committee.

The usual methods of making piston rings are outlined in the preceding pages, and these are supplemented with the following notes and with a short account of the methods employed by one of our leading piston-ring manufacturers.

The best method for the ordinary motor engineer who cannot obtain the particular sizes he requires is to obtain, either from a firm of motor factors, such as Messrs. Brown Bros., Ltd., London, or from a firm of piston specialists, such as the British Piston Ring Co., Ltd., Coventry, a piston-ring pot or casting made for this purpose.

It is necessary to use a special grade of close-grained cast iron—usually to aircraft or B.S.I. specifications—cast by the centrifugal process so as to be free from blow-holes or impurities.

The " Brico " centrifugal casting for piston rings is parallel over most of its length, and has a flange for holding it to the chuck or face plate. These castings are made in 8-in. lengths, and in a variety of diameters from 2 in. (solid) to 6·2 in. (outside) × 5·27 in. (inside) diameter; the outside diameters vary by ·20-in. steps.

It is usual to plain-turn the inside and outside diameters, and to part off the rings in the lathe. The rings are then split, as previously described, clamped up and ground on their outer surfaces; the parallel sides are also ground to finished dimensions, so that the rings bed flat in their grooves.

The following is an account of the material and methods employed by the Light Production Company, Ltd., one of the largest piston-ring manufacturers in this country; it is given in some detail, as the information contained indicates the great care and accuracy necessary in making automobile piston rings.

Machining

The cast pot is set up in an automatic lathe, turned and bored. By the centrifugal casting process all impurities are thrown to the centre of the

" pot." These are all machined away by the boring process, leaving only the perfect iron of the outside of the pot to be parted off into rings, which is done by stepped gangs of cutters.

After parting off, the rings first appear as separate units, slightly larger all over than the finished product. In the next operation the rings are faced on the sides and the internal edges are bevelled. The slits are then cut with a small slitting saw.

It is perhaps of interest to note that all this type of rings is cut with a straight slot at 45°. The exception to this rule is in the case of two-stroke engines, the rings for which are generally slit at right angles and provided with a peg hole. Considerable experience with step-cut, double-coil, and other types of rings of greater or less complication has proved that the utmost satisfaction can only be obtained from a ring with slant joint. These rings are sealed with oil at the joint and do not leak, whilst the elimination of the complicating factors present in other types enables the production of a ring which is dead true and flat, without any variation in thickness throughout its entire length.

Hammering

After slitting comes the hammering operation, having as its object the imparting of increased resilience to the ring and the equalisation of pressure all round the wall of the cylinder. This operation is effected in machines specially designed and built in the works of the Light Production Company, Ltd. The ring is held in a die and slowly rotated. It is at the same time struck a series of graduated blows on its internal periphery with a blunt-edged chisel-shaped tool. The blows are lightest near the slot and become more severe at the point opposite the slot. The success of this important operation depends on the accuracy of the cam which controls the intensity of the blow. Much experiment in this connection has resulted in the perfection of this operation, so that the final product is dead round, bears evenly in the cylinder, and retains its true circularity under the high temperatures in which it has to work.

Grinding

After hammering, the rings are surface-ground on both sides, for which operation they are held on rotating magnetic chucks. This is a finishing operation, and is conducted with great care. On it depends the true flatness of the ring, and hence the efficacy of the seal between the ring and the lower face of the piston slot. The width of the rings is accurate to within limits of plus or minus a quarter of a thousandth of an inch.

The final stage in the manufacture of L.P.C. piston rings is external grinding. For this purpose the rings are contracted on to a mandrel, with the joint closed by a highly ingenious method. The outside of the ring is then finished-ground to a tolerance of plus or minus a half-thousandth of an inch of the diameter of the cylinder, thus ensuring that it will be dead round when again compressed to its working position in the engine.

Piston-ring Measurements and Limits

It is essential in making piston rings of a given size to work to proper limits, as regards the diameter, thickness, and ring gap. In order to illustrate the accuracy required, one cannot do better than to quote an actual example of a high-grade automobile engine having six cylinders of $3\frac{1}{4}$-in. (3·25-in.) bore.

Here the thickness of the upper rings is ·1230 to ·1235 in., the width of the piston grooves being ·1250, so that there is a maximum clearance of ·002 to ·0015 in. between the two. It will be observed that the allowable limit in the ring thickness is ·0005 in.

Similarly in the case of a $\frac{3}{16}$-in. piston groove. Here the manufacturing tolerances would be ·1875 to ·1865 in.—that is, ·001 in. The piston rings would have manufacturing limits of ·1860 to ·1865 in., the difference allowed being ·0005 in. The maximum and minimum ring clearance in the slot of the piston would be ·001 to ·0015 in.; the rings would be selected so that a ·1865-in. one did not apply to a ·1865-in. piston slot.

The clearance allowed between the two ends of the ring, i.e. the slot, when compressed in the cylinder, and when new, for the above case is ·010 to ·015 in.

Test for Quality

A test for the quality of the metal, or springiness of the ring, is to measure the force necessary to close the gap in the ring. This should be from 6 to 8 lb. in the case of a ring of $\frac{1}{8}$-in. thickness, and from 8 to 10 lb. in the case of a $\frac{3}{16}$-in. ring.

Piston-ring Clearances

The concentric type of piston ring must fit its piston slot correctly, being neither too slack (or blow-by will occur) nor too tight (or the ring will jam in its slot and fail to hold the gas pressure).

The *correct amount of side clearance* between the piston ring and the piston slot is ·0015 in. for rings up to 6 in. diameter and ·002 to ·003 in. for rings from 6 to 12 in. in the case of *cast-iron pistons.*

For *aluminium-alloy pistons*, the side clearances are ·002 to ·003 in. for diameters up to 6 in., and ·003 to ·004 in. for diameters from 6 to 12 in.

A good test for the correct fit of a piston ring is to hold the piston with its axis horizontal and then lift the ring so that its lower end comes into contact with the bottom of the piston slot. Upon releasing the ring, it should *just slide down to the bottom* of the upper part of piston slot.

The A.E.C. oil-engine piston rings are given a side clearance of ·003 to ·004 in., and a gap clearance of ·008 in.; the pistons in question are of approximately 4 in. diameter.

The method of checking the gap in the case of the A.E.C. Diesel-engine piston rings is illustrated in Fig. 284. In this example three compression rings are fitted at the top of the piston and one oil-scraper ring in the skirt portion below the gudgeon pin.

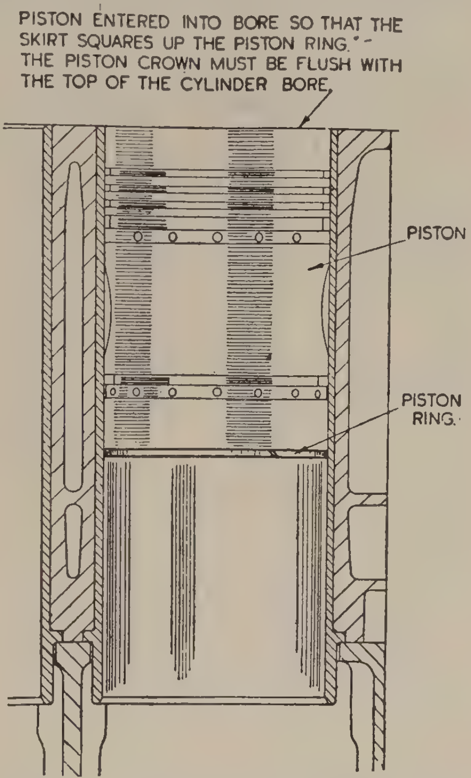
PISTON ENTERED INTO BORE SO THAT THE SKIRT SQUARES UP THE PISTON RING. - THE PISTON CROWN MUST BE FLUSH WITH THE TOP OF THE CYLINDER BORE
PISTON
PISTON RING.

Fig. 283.—Testing A.E.C. Piston Rings in Cylinder.

The piston-ring grooves and the backs of the rings should first be well cleaned, and the rings then replaced in their original grooves and checked for side clearance with a feeler gauge.

If the clearance is in excess of ·015 in. new rings should be fitted. To test the ring gap, place the ring in its correct cylinder, about half-way down, squaring it with the bore by means of a piston (without rings) placed as shown in Fig. 284 and inserted from the top of the block. The piston-ring gap, when checked with a feeler gauge, should not exceed ·012 in., otherwise a new ring should be fitted.

The Leyland oil-engine piston rings have side clearances of ·003 to ·005 in. and gap clearances of ·007 to ·009 in. The *gap clearances* are measured with a feeler gauge (Fig. 284) when the rings are inserted squarely in their proper cylinders. The British Piston Ring Company recommend a standard clearance of ·002 to ·003 in. per in. diameter of piston for rings up to 6 in. in the case of *water-cooled engines*, and ·004 to ·005 in. for *air-cooled engines*.

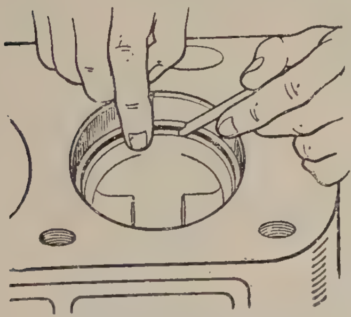

Fig. 284.—Measuring the Gap Clearance of a Piston Ring.

If any doubt exists, it is best to give a slightly greater clearance than a slightly smaller one, for in the former case the worst that can happen is a small leakage of compression or gases under pressure, whereas in the latter case increased cylinder friction and eventual wear may occur. As oil-scraper rings are now always fitted, there will be no appreciable oil leakage on account of a slightly larger gap.

The following table shows the piston-ring clearances advocated by the Aluminium Company of America.

TABLE OF PISTON-RING CLEARANCES

Piston Diameter, in inches.	*Ring-gap Clearance, in inches.*	
	Step-cut Rings.	45° *Diagonal-cut Rings.*
3·0	·007	·005
3·5	·009	·007
4·0	·012	·009
4·5	·015	·011
5·0	·019	·014

Measuring Piston Rings

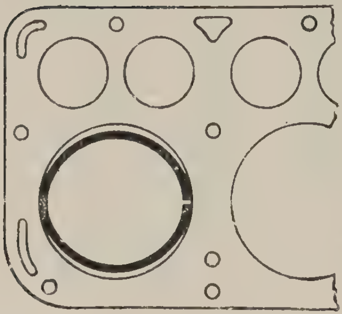

Fig. 285.—Showing how a plain split ring touches the cylinder at three places only. By the special hammering or grinding processes described the ring is made to touch all round.

When it becomes necessary to measure the diameter of a piston ring, care should be exercised, otherwise a false result will probably be obtained. The act of compressing the sides of the ring in order to close the gap, before attempting to take measurements, is apt to distort the ring, that is to say, to make it oval in shape (Fig. 285). The ring should be compressed evenly, with semi-cylindrical pieces of wood or by means of a piece of string, so that it is contracted with a uniform pressure. The diameter should be measured at several places, with the gap closed, and the mean value taken.

A much better method is to use a device of the type shown in Fig. 286, and known as a "Bricometer." This consists of a graduated loop of steel tape, clearly marked in millimetres from 50 to 150; it can be fixed to a convenient part of the bench. The piston ring to be measured is merely inserted in the loop, and the tape pulled taut by means of the ring provided for the purpose. The tape is so graduated that the diameter (*not* the circumference) is read off directly at the reading mark shown in the illustration.

When inserting the piston ring into the loop of the tape place the gap of the ring towards the bottom of the loop so that you can see when it is closed.

The tape is graduated in millimetres, but half a millimetre can easily be judged by the eye if necessary. Be sure you order piston rings large enough, so that the joint can be filed to make a good fit in the cylinder.

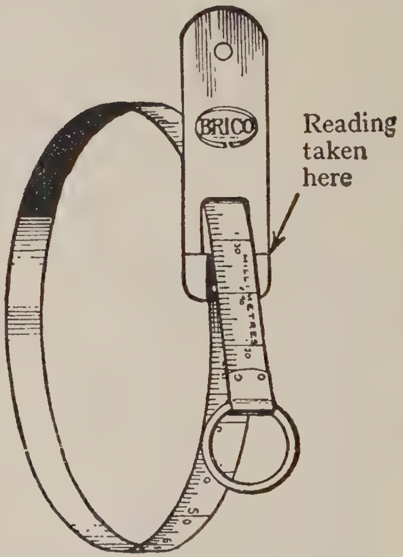

Fig. 286.—The "Brico" Piston-ring Measuring Device.

If you are measuring a badly worn piston ring, place it back in the cylinder and insert a distance piece in the gap, then measure the ring, together with the distance piece, in the meter to get the correct diameter of ring required.

The Practical Fitting of Piston Rings

The ordinary garage engineer is, perhaps, not so concerned with the materials, methods of manufacture, and other technical facts in connection with piston rings, but rather with the matter of fitting new rings into his pistons.

The motor engineer always keeps spare rings of various standard sizes and oversizes. The new ring can be compared with any worn ring very readily, both for dimensions and for spring. If one ring be placed edgewise on the other and the latter be compressed with the former, the relative degrees of springiness can at once be ascertained (see Fig. 287).

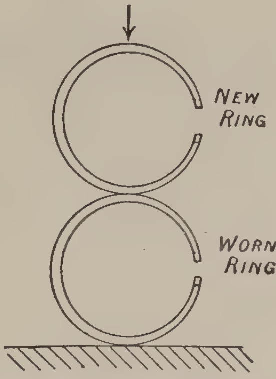

Fig. 287.—Method of testing New and Worn Piston Rings.

Otherwise the only thing to do, after cleaning both the piston rings and piston grooves, is to test each ring in its groove for clearance; or, better still, micrometer the ring and measure the groove, so that the total clearance is known; this should not exceed ·002 in.

The ring should be examined for undue wear and grooves on its outer surface, and finally should be placed in the working part of the cylinder barrel (Fig. 284), and the gap measured with a feeler gauge; if the gap clearance exceeds about ·02 in., the ring should be rejected as this clearance will allow an appreciable gas leakage.

The amount of the gap clearance varies with different engines and cylinder diameters. For air-cooled engines and for larger diameters of cylinder more allowance should be made.

The piston ring should have such a flexibility that about 8 to 10 lb. is required to close the gap in the case of a 3-in. ring of $\frac{3}{16}$-in. thickness or width.

In fitting new rings in the piston, place the ring in the piston groove and move the ring entirely around the piston, holding the ring firmly.

If the piston grooves are stepped (as shown in Fig. 271), the steps should be turned out before attempting to fit the new rings.

If the ring does not fit its groove—that is to say, has to be forced in—or will not enter, it may be reduced in width by laying it on a sheet of fine emery cloth fixed firmly on a flat block; the ring should be held flat as indicated and given a rotary movement. It should be tested from time to time in its appropriate groove until it just slides in without any suggestion of slackness. The sides must be kept quite parallel.

Another makeshift garage method for reducing piston rings is to make a board with a slightly raised boss (Fig. 288) on which the piston ring is sprung; the ring should just project above the boss. The board is screwed to the bench or held in a vice, and the surface of the ring reduced with an emery-cloth-covered board as indicated. The piston ring should never be filed, since it has to be an accurate fit in its groove.

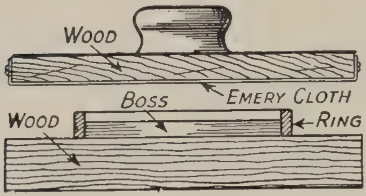

Fig. 288.—Method of reducing Piston-ring Width.

A useful device for holding piston rings in order to grind or emery-cloth them flat is illustrated in Fig. 289. It consists of a block of hard wood having a recess turned in one of its flat faces to hold the ring. The wood is sawn down, as shown, so that when gripped in the vice it firmly clamps the ring.

Perhaps the best method, when the work is done in a well-equipped shop, is to employ a magnetic chuck or face-plate, and to grind the one face of the ring down until it fits.

Sometimes a light skim can be taken from one side of the piston-ring groove in order to obtain a proper working fit. Each ring should be fitted to its own groove, and only replaced in its groove, as there may be variations between the different grooves.

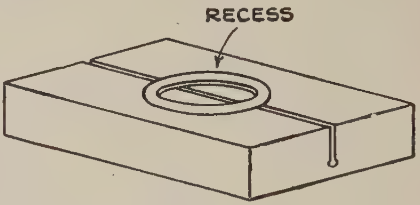

Fig. 289.—Wooden-block Clamp for Piston-ring Surfacing.

When fitting piston rings, it is better to fit them in the cylinder first, and for this reason the ring gaps usually require filing, until the rings fit with the allowable clearance. To file the gap, use a thin, flat ward or key file of about 6-in. length.

The ring should be held in the vice as shown in Fig. 290; copper or lead vice clamps must be used in the vice or the sides of the ring will be damaged. The ring is propped open with a piece of wood, as shown, so that the gap is increased to about $\frac{1}{4}$ in. or so, in order to facilitate the filing process.

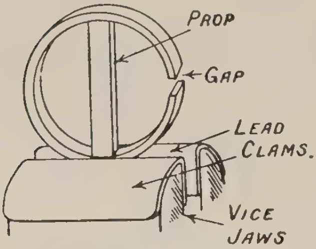

Fig. 290.—Holding the Ring.

Care should be exercised in the filing operation that the two sides of the diagonal slot remain always parallel; this can be tested by removing the prop and pressing the two sides of the slot together with the fingers; any want of parallelism will be at once evident when the gap is thus closed.

Piston-ring Filing or Grinding Clamps

Where piston-ring fitting is done on a routine basis it is advisable to employ one or other of the proprietory makes of piston-ring clamps for holding the rings whilst filing or grinding the gap sides.

Fig. 291 illustrates the Churchill device for holding piston rings. It consists of a metal block having a series of parallel slots of different widths to suit various sizes of rings. For diagonal-cut rings the block has a 45° slot across the parallel slots, as shown in Fig. 291; for step-cut rings the filing slot is at right angles. The block is held in a vice and a ward file is used in the filing slot; both sides of the ring can be filed at the same time with this device.

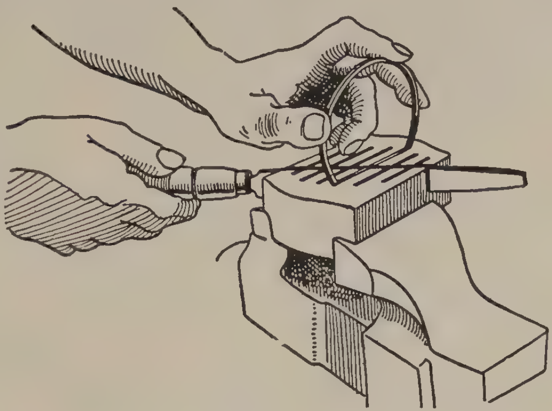
Fig. 291.—The Churchill Piston-ring Jig

The device shown in Fig. 292 is very useful for filing the slot of a piston ring. It consists of a rectangular-section steel bar which has a hole at one end for placing over a pin or cylinder stud. The bar has a vertical file, of narrow section, held at its ends in suitable brackets attached to the bar. The piston ring is held against the V-block shown, and it slides up and down the bar with this block, with the piston ring straddling the file. Three slots are provided in the file bracket to enable the file to be used at 45° in either direction, or vertically.

The McCarthy piston-ring clamp shown in Fig. 293 consists of two similar metal blocks between which the ring is held. The two members are connected together below by means of a circular metal spring—similar to that of a "Bulldog" paper clamp. The ring is held securely in the clamp, and as the latter is chamfered away near the top the diagonal-gap type of piston ring can be filed, as well as the step-cut one. The clamp can readily be secured in an ordinary vice.

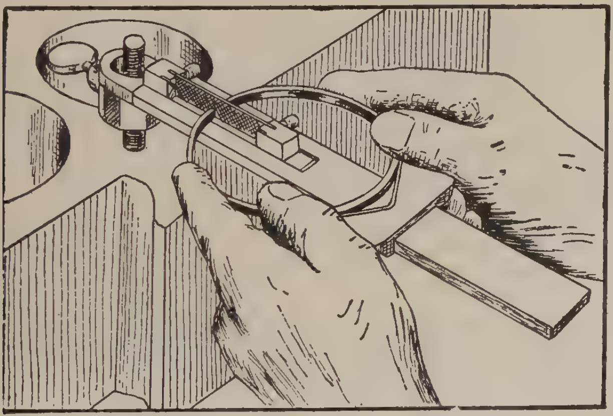
Fig. 292.—Piston-ring Slot-filing Jig.

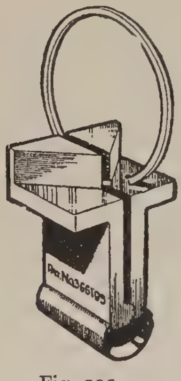

Fig. 293.—
McCarthy Piston-
ring Clamp.

Filing Step-cut Piston Rings

Fig. 294 illustrates a method of filing the slot in step-cut piston rings. This form of ring cut makes it difficult to hold the ring with the hands while filing, and also results in breakage, since the ring must be expanded for proper filing of the slot. The extreme ends of the ring must be filed and not the mating end of the cut.

To eliminate the danger of breakage, hold the file in the vice jaws, the file being indicated by (1) in Fig. 294. The file should be held in a vertical position, and to protect the ring against breakage and distortion fasten strips of wood (2) to the ring with wood screws. Fit the wood supporting members close to the ring opening, then expand the ring to pass over the file and hold it in the expanded position with the wood screws. The tension of the ring should be just enough to keep the ends in contact with the file. In filing, grip the rings as close to the ends as possible and use a stroke with even pressure. Releasing the screws will permit measuring the ring gap without removing the wood strips.

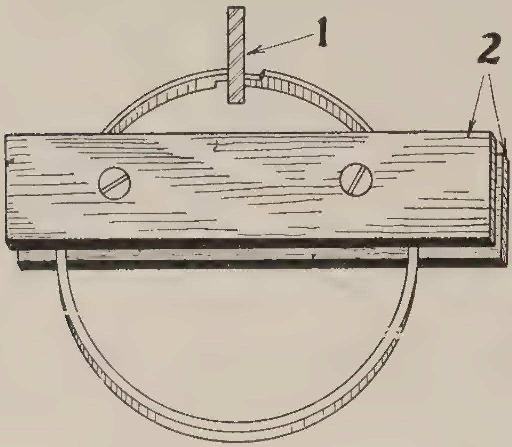

Fig. 294.—Filing Step-cut Piston Ring.

Replacing Piston Rings

It is usually easier to replace than to remove piston rings. The expert mechanic can always replace the rings in their proper slots, without breaking them, with his fingers alone. The secret is to get a slight spiral twist on the ring so that one end is farther down the piston than the other and it thus bridges the piston grooves which it is intended to pass over. This method, however, requires care or the ring may be broken.

The less-experienced worker should employ the three-strip method. Narrow strips of metal should be used, and the strips should be of steel or hard brass, in order not to distort. One has used three pieces of an old hack-saw blade, with the teeth ground off, for this purpose. Do not force the rings unduly, or you may easily fracture them. Fig. 295

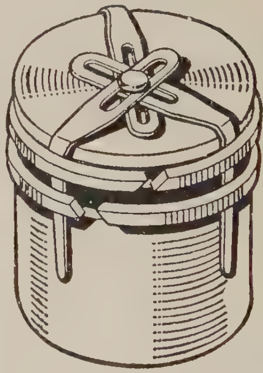

Fig. 295.—Device for replacing Piston Rings.

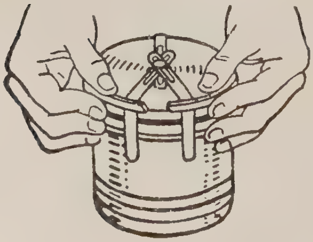

Fig. 296.—Replacing the Rings.

shows a useful device, by the British Piston Ring Company, for replacing rings; the method of using this is shown in Fig. 296. The three adjustable metal strips enable the device to be used on pistons of varying diameters.

When all the rings are replaced, arrange them with their slots at 120° to each other, so that they are equally spaced on the piston, when replacing the latter.

Fitting Piston Rings by the Peening Method

As we have already pointed out, many piston-ring manufacturers, after turning and splitting rings a little oversize, when closed clamp them with ends together and grind them to shape and size. If the rough rings are slipped into a cylinder of suitable diameter and long enough to hold several rings, they may be clamped together between the small flanges on an arbor, slid out of the cylinder and ground or turned to size.

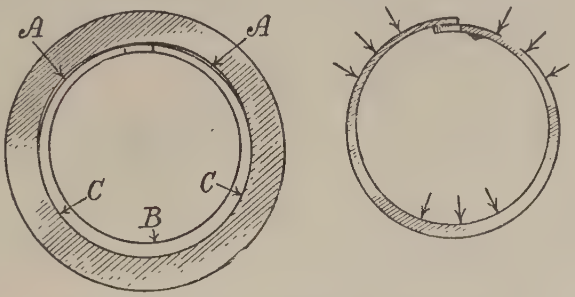

Fig. 297.—The Peening Method of fitting Rings.

The illustration in Fig. 297 shows a ring inside the cylinder ready to be clamped on the arbor. It will be observed that the ring only touches at A and B. If left in this condition it would wear most at A, and after a little use dark spots would appear at C, and leakage would occur there.

To make a ring tight and to ensure that it will wear evenly, put it over an arbor and peen, with a suitable hammer point, the outside at each side of the point A, so as to bring the point of the ring in a trifle, as shown in the right-hand illustration (Fig. 297). Do this to both sides, and then bring the ring back to perfectly round by peening on the inside at the place marked B. This will throw the points out and, if carefully done, will give a round ring that will require very little fitting to ensure a perfect seal.

To test a ring when fitting, rub Prussian blue in a very thin film on the outside. Insert it in the cylinder it is to be used in, and rub to show the bearing.

Careful peening will make filing unnecessary. It is well to *practise on some old rings first.* Be sure not to hit too close to the edges of the ring. Use a light hammer, and tap gently so that you can control the operation better.

Oil Control or Scraper Rings

Practically all modern engines are now fitted with special piston rings for the purpose of regulating the amount of oil on the cylinder walls, so that this quantity is just sufficient for its purpose of lubrication, but not enough to cause excessive carbon deposit. The use of these scraper rings—as we

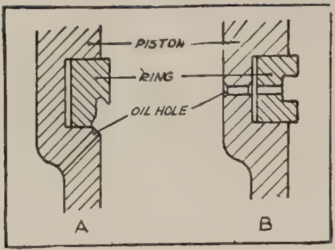

Fig. 298.—Showing Two Types of Oil-control Piston Rings. A—Single Bevelled. B—Grooved.

shall term them—has resulted in greatly reduced carbon deposits, and improved oil economy in modern engines.

Scraper rings are usually beneficial in older-type engines which suffer from heavy oil consumption; they should therefore be fitted in cases where it is decided not to rebore the cylinder and fit new pistons.

The scraper ring is usually arranged above the gudgeon-pin hole, but the earlier practice was to fit it near the foot of the piston skirt. In some cases there are two compression rings and one scraper ring, the latter always being the lowest ring. In the *case of high-speed Diesel engines*, three or four compression rings and one and sometimes two scraper rings are fitted, for these engines work at higher compression and combustion pressures than petrol engines. When two scraper rings are fitted one is usually above and the other below the gudgeon pin, viz. at the foot of the skirt.

The principle of the scraper ring (Fig. 298) is to provide a scraping edge, so arranged that when the piston is moving downwards the excess of oil on the cylinder walls is removed by this edge through *suitable holes, or slots, in the piston*, to the inside of the piston, whence it drains back into the crankcase.

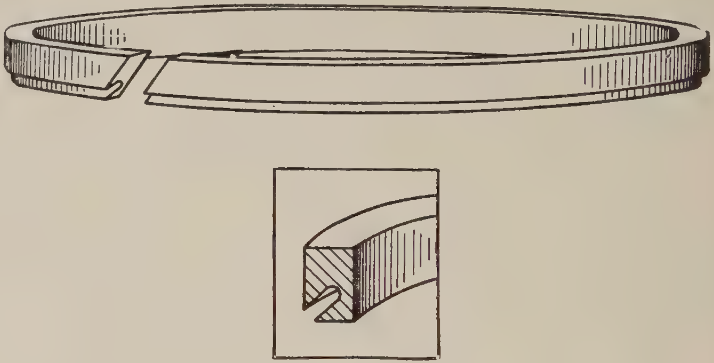

Fig. 299.—The Superoyl Piston Ring.

Figs. 299 and 300 illustrate some typical oil-control rings now used on petrol engines.

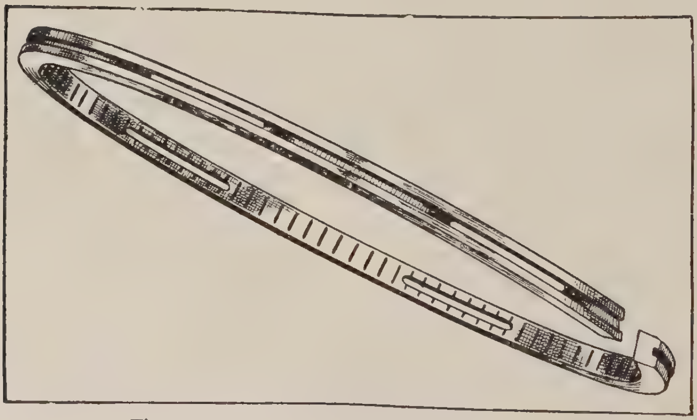

Fig. 300.—The Wellworthy Oil-control Ring.

When overhauling the piston it is important to see that the oil-return holes, or slots, are quite clear.

Fig. 301 shows three different types of oil-control ring made by the British Piston Ring Company, with sectional views (on right) corresponding to the outside ones on the left.

The ring shown at A has its upper side bevelled away. The ring B has its lower portion turned off so that it is quite clear of the cylinder wall, whilst the ring C has a central groove turned in it, slots being cut right through the recess at regular intervals. In each case, owing to the reduced area of the ring in contact with the cylinder wall, the bearing pressure on the wall is greater than for a plain compression ring of similar external dimensions. In each of the rings described an oil-drainage hole is arranged from the piston-ring slot to the inside of the piston.

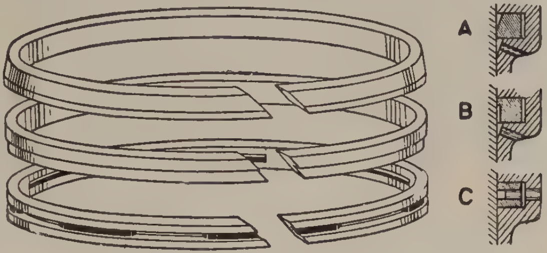

Fig. 301.—Some Common Oil-control Rings.

Delayed-action Scraper Ring

When an engine is properly run in, and for periods up to about 15,000 to 20,000 miles from the new condition, the piston rings behave satisfactorily, but as cylinder and ring wear then begin to occur, the oil consumption increases progressively until after about 30,000 miles or so it becomes excessive and new rings must be fitted.

To extend considerably the life of the engine before new rings are necessary a new type of piston ring, known as the Hepolite delayed-action scraper ring, is now fitted. When new, this slotted channel-section scraper ring (Fig. 302) has a large number of flats machined across its periphery which allow the free passage of oil to the upper rings. As the ring wears, the flats gradually disappear, and eventually, at about the time an ordinary ring requires renewal, the Hepolite ring comes fully into operation as an efficient scraper ring, thus prolonging the satisfactory oil consumption and delaying the decarbonising period.

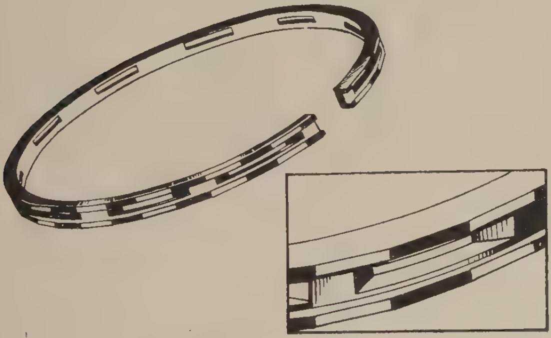

Fig. 302.—The Hepolite Delayed-action Scraper Ring.

The piston must, however, have another oil groove, as this ring is additional to the ordinary set of rings. If the piston has two scraper rings, then the lower one can be replaced by a delayed-action scraper ring and the upper one given a more drastic scraping action.

With this Hepolite ring the normal oil consumption of the engine can be retained for 35–40,000 miles.

Piston-ring Troubles

The following are the principal piston-ring troubles which are likely to occur in petrol and high-speed oil engines; the causes of these troubles are also given.

(1) *Gas Blow-by.*—This is caused by excessive piston-ring gap or to unequal bearing of the ring on the cylinder walls. Rings which have become worn or have lost part of their original elasticity also cause "blow-by."

If on examining the cylindrical working face of a piston ring it exhibits blue or blackened areas, this indicates that the gases have been blowing past the ring; it should therefore be replaced by a new ring.

(2) *Gummed Rings.*—Due to the use of unsuitable engine-lubricating oil or to the formation of carbon behind the rings in their slots. Excessive lubrication or piston wear, resulting in much oil passing the piston, are other causes.

(3) *Loose Rings.*—These result in noisy operation and loss of gas pressure and also compression.

(4) *Piston-ring Click.*—This is usually caused by the rings being too tight a fit in their slots; also by fitting new rings in worn piston slots without having turned the shoulders away, so that the rings tend to wedge in their grooves.

(5) *Excessive Friction.*—Due to insufficient gap clearance or rings too tight a fit in their slots. The use of rings which are too thick (radially) may also cause this trouble.

(6) *Broken Rings.*—These are caused by too small a gap when first fitted or by faulty fitting, so that the rings are subject to thermal stresses which eventually cause fracture. Unsuitable piston-ring material is another possible cause.

CHAPTER 9

THE PISTON

Making New Pistons

ALTHOUGH many manufacturers of motor-car engines of repute make provision for the supply of practically all spare parts likely to be required, including both oversize pistons and piston rings to suit worn or reground cylinders, there is a fairly large number of instances of less recent engines coming in for repair in which no provision has been made for such items. In many cases the engines are of earlier design, no spares being obtainable.

The making of new pistons for worn or reground cylinders is a job which every modern motor-workshop or garage should be in a position to undertake. Fortunately this is quite a straightforward operation, but it requires a specific knowledge of the following points: namely, (1) *the correct material*, (2) *the correct limits*, or *clearances*, and (3) the *proper finish*. Incidentally, pistons intended for replacement purposes should be *accurately made* to the design of the pattern piston, and should certainly be of the *same weight* as existing pistons. If a set of pistons, say, is to be made for a four-cylinder engine, these need not, generally speaking, be of identical weight with those they replace, but they must *all* be of equal weight, otherwise the engine may be out of balance. If, of course, the *pistons form part of the balanced masses*, as in the case of a V-twin or single-cylinder engine, where the flywheel balance weight is carefully designed to partially balance part of the reciprocating forces, then the pistons must be made the same weight as those they replace.

If *aluminium-alloy* pistons are made to replace cast-iron ones in the case of balanced engines (e.g. two-cylinder opposed, four-cylinder vertical, and six-cylinder vertical), then, as long as they are of equal weights, there will actually be a marked advantage in the reduction of the total weight of the reciprocating parts in making the pistons of this lighter metal. Here it should be mentioned that the term " piston weight " refers to the weight of the bare piston plus piston rings and gudgeon pin (or pin bushes).

Fig. 303 illustrates a modern aluminium-alloy piston and gives the usual nomenclature adopted for the various parts. The piston shown has a special design of head and skirt, the latter being to some extent separated from the piston crown by means of the horizontal slot shown. This slot acts partially as an oil-scraping device, but its main object is to allow the skirt to be split by means of a vertical—or in some cases inclined—slot so that the spring of the skirt will always maintain it in contact with the cylinder walls and thus prevent *piston slap* when the engine is cold.

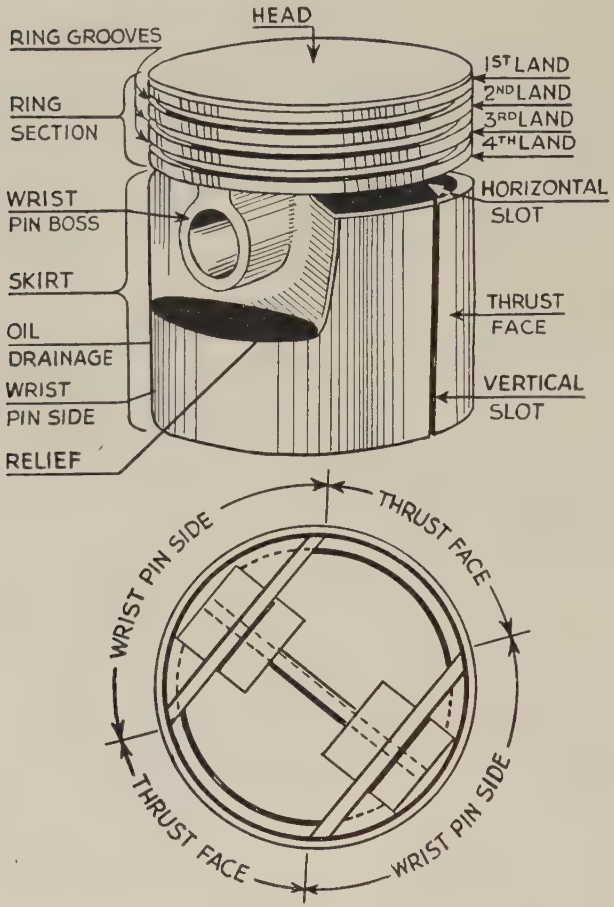

Fig. 303.—A Modern Piston made in Aluminium Alloy.

There are three piston grooves, the lower one being for an oil-scraper ring. This design of piston is very light in weight.

Measuring Fit of Piston in Cylinder

The clearance between the piston and its cylinder when new will depend upon certain factors, including (*a*) the cylinder diameter; (*b*) design of piston; (*c*) material of piston, and one or two other minor items, so that no hard-and-fast rule can be given for piston clearances which will be applicable to all engines.

Under the circumstances it is advisable to ascertain the engine manufacturer's values before checking the fits of the pistons in worn engines. As will be shown later, when the worn clearances exceed certain values it becomes necessary to rebore the cylinders and fit new pistons.

There are two methods generally used for measuring piston clearances, as follows: (1) by direct measurement with micrometer and cylinder gauge; (2) by feeler gauge.

In the former case the diameters of the cylinder are measured at several places until that showing the greatest value is found. The diameter of the piston at the same working position is then measured; this value, subtracted from the previous maximum value, then gives the maximum clearance. Another method, sometimes preferred, is to measure the clearance at the maximum skirt-diameter working position in the cylinder and of the piston skirt; this gives a better indication of the cold clearances.

The feeler-gauge method (Fig. 304) uses a long narrow feeler gauge of the type shown in Fig. 38. The feeler is inserted between the piston (without its rings) and cylinder wall. The measurement is made from the bottom of the cylinder block—since there may be an unworn ridge at the top end—and on that part of the piston skirt which is at right angles to the gudgeon-pin axis, i.e. the minimum diameter in the case of oval pistons.

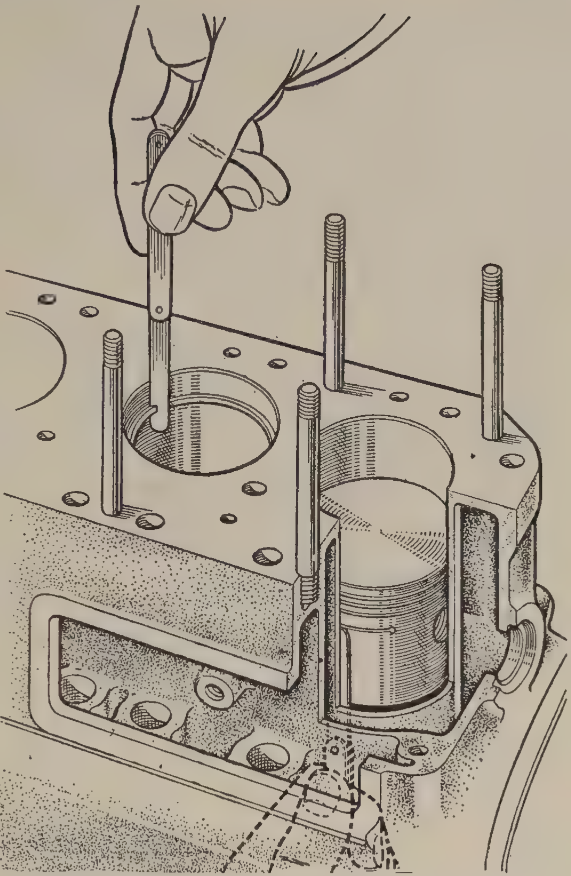

Fig. 304.—Measuring Piston (right) and Piston-ring Clearances (left) (Austin engine).

In the case of the Austin A40 engine, which has split-skirt pistons, the new clearance at the skirt should be ·0015 in.

In some instances a spring balance is employed, so that the feeler gauge can be pulled past the piston with a stipulated force—usually of a few pounds only. In the case of the Chrysler piston (Fig. 305), a ½-in. wide feeler gauge is passed the whole length of the piston and pulled with a force of 5–7 lb. A ·002-in. gauge should just move past the piston for correct clearance.

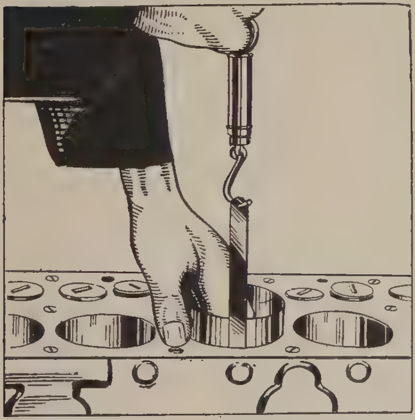

Fig. 305.—Checking Piston Clearance in its Cylinder, using measured pull on Feeler Gauge (Chrysler).

The Gudgeon-pin Fit

In pistons where the gudgeon pin is to be a somewhat tighter fit than the usual rocking fit in the small end, it is now usual to specify the "*thermal fit*" in the piston bosses, such that when the piston is placed in boiling water it becomes heated sufficiently to allow the cold gudgeon pin to be readily pushed into position, as previously described in detail.

When the gudgeon pin is secured to the small end by a pinchbolt, it must be a rocking fit in the piston bosses. Thus in the Vauxhall and Bedford engines the gudgeon pin should be no tighter than a thumb-push fit, otherwise there is a risk of piston distortion.

Piston Alloys

The modern aluminium-alloy pistons are made from special alloys, which are very much harder and stronger than pure aluminium but of practically the same weight.

As these aluminium alloys are about one-third to two-fifths the weight of cast iron, it is obvious that an appreciable saving in weight can be obtained with aluminium-alloy pistons. For practical reasons connected with the design and casting of these pistons it is necessary to allow rather more metal than for cast iron, but a weight reduction of from 30 to 50 per cent. over the latter metal is usually obtained.

Many of the earlier alloy pistons were made from an aluminium alloy known as 2L8, consisting of 11 to 13 per cent. copper and the rest aluminium. This alloy has a tensile strength in the chill cast of 12 tons per sq. in.; it is about 50 per cent. stronger than pure cast aluminium.

Another popular alloy is the No. 3L11, containing from 6 to 8 per cent. of copper, 1 per cent. of tin, and the rest aluminium.

More recently stronger aluminium alloys known as "*Y*" *Alloys* and *R.R.*, or *Hiduminium* alloy, have been used for pistons. These alloys, in their appropriate grades, can actually be die-cast to within very small limits, so that the minimum amount of machining is required.

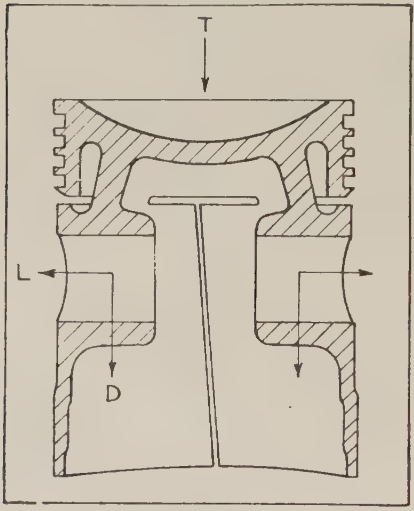

Fig. 306.—The B.H.B. Piston.

These modern alloys give sharp impressions of the moulds and retain their strengths to a much higher degree at the working temperatures in the cylinder than the earlier alloys. They can be machined in the same manner as aluminium and give a high degree of polish. Diamond-turning tools are often used in cases where a large number of pistons of similar design have to be machined.

A well-known aluminium piston is the B.H.B. one, shown in Fig. 306. It is so designed that the piston thrust T, due to the explosive pressure developed in the cylinder and the connecting-rod thrust, causes a downward force D and an outward force L. The latter force is arranged to expand the piston against the cylinder walls by a predetermined amount. With this type there is no piston-slap effect. With split-skirt pistons, as previously stated, the split side is always arranged on the least-pressure side, i.e. the explosion thrust is taken on the solid face in all cases.

Invar Strut Piston

As the motor engineer may come across this type of piston during engine repair work, it is proposed to describe it here. This piston has four nickel-steel struts cast integrally between the piston bosses and the metal of the piston skirt. The special grade of nickel-steel used is that known as *Invar*; it has a very low heat expansion coefficient and for this reason is used for measuring tapes and clock pendulums. The struts in question are so proportioned that the expansion of the skirt is practically the same as that of a cast-iron piston. Two cylindrical saw-cuts separate the skirt from the head and boss portions, and the skirt is partly slotted to enable the strut members to give better expansion characteristics.

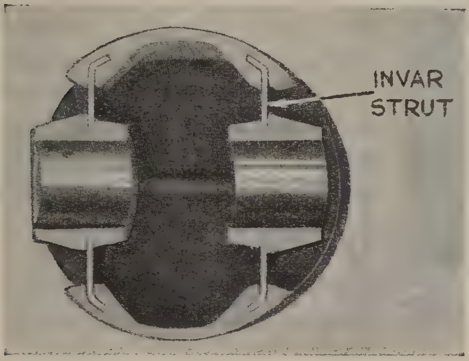

Fig. 307.—Sectional View of Invar Strut Piston, showing Nickel-steel Struts.

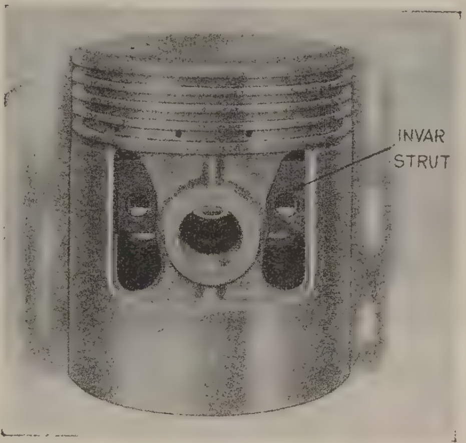

Fig. 308.—The Invar Strut Piston.

There is no piston slap with the Invar strut design.

The A.E.C. Pistons and Piston Rings

The A.E.C. oil engines employ aluminium-alloy pistons of the plain-skirt pattern (Fig. 86, page 94), fitted with five or six piston rings, according to the type of engine. The pistons and their connecting rods are numbered in sequence, commencing with No. 1 at the front or radiator end; they must be replaced in their proper cylinders.

The clearance at the skirt of the 105-mm. bore piston is ·006 in. to ·008 in. when new; that of the 115-mm. piston is ·008 in. When new, the clearance of all piston rings in their respective grooves is from ·003 in. to ·0045 in. Rings which show blackened or discoloured patches should be replaced with new ones. When fitting new rings, a gap of ·008 in. should be allowed between the ends, when the ring is fitted square into the cylinder barrel.

Truing Gudgeon-pin Holes

In the case of some engines, e.g. the Morris and Wolseley ones, in which the gudgeon pins are clamped to the small end of the connecting rod and have their bearings in the piston bosses, the manufacturers do not advise the reaming out of worn holes in the bosses (and also of the unworn small end) and the fitting of oversize gudgeon pins, and no provision is made to supply such pins. In other instances, notably where the gudgeon pin is a tighter fit in the piston bosses and a bearing fit in the small end, should the pin become slightly loose in the bosses it is usually permissible to ream out the holes in the bosses and small-end bush and fit an oversize gudgeon pin. The amount of metal taken out of the holes is very small, so that the diameter increase is only a few thousandths of an inch.

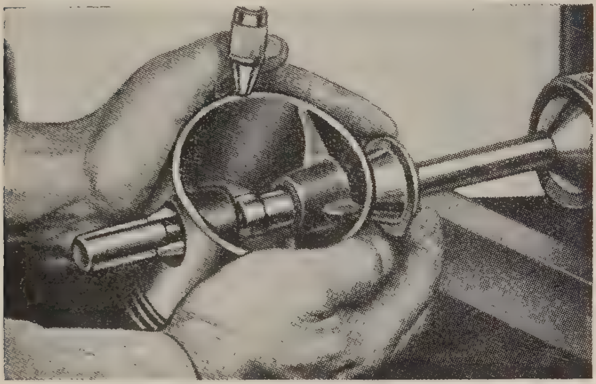

Fig. 309.—The Delapena Internal Hone shown in use truing Gudgeon-pin Holes.

Although it has hitherto been the custom to ream out the gudgeon-pin hole when a slightly larger size of gudgeon pin is fitted in order to suit the reamed-out small-end bush, the honing method is now employed for this purpose. It has been found that, just as with cylinder bores, the honing stone gives a more accurate hole and a better surface finish than that of the hard-steel reamer's teeth.

Hones similar to those used for cylinder reconditioning are now available for bushes and piston-pin holes.

They are fitted with a pilot pin, or are of sufficient length to do two or more bushes at a time, as in gudgeon-pin bushes. Fig. 309 shows the Delapena internal hone, which has two solid mandrel guides of the same length as the abrasive stone and an expanding tapered wedge device to increase the honing diameter. This hone will correct errors of out-of-roundness and taper, and it will finish holes with a high degree of accuracy and surface texture. The manner in which it corrects for out-of-roundness is shown in Fig. 310, in which the left diagram indicates the initial shape of the hole and the right one the stage at which the hole is nearly cylindrical. Hole diameters to within ·0001 in. ($\frac{1}{10,000}$ in.) can be obtained with this design of internal hone. For piston holes the hone is rotated at 250–750 r.p.m., and the piston is hand-held.

Incidentally these bush hones are equally applicable for the steering bushes, front axle, spring shackle pins, etc.

The hones are usually operated by means of an electric drill of the portable pattern. Alternatively the hone can be operated by hand or in an ordinary hand-drilling machine.

Another method is to use a reamer of the correct size, held in the collet or self-centring chuck of a lathe. The piston is then held in the hand and the gudgeon-pin hole reamed out. The expanding-type multi-bladed reamer illustrated in Fig. 311 is recommended for the truing or enlarging of gudgeon-pin connecting-rod holes when the reaming method is employed.

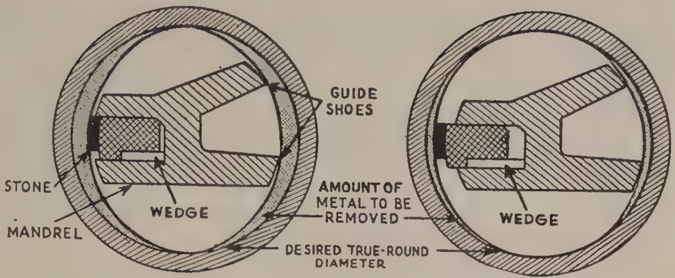

Fig. 310.—Principle of Internal Hone.

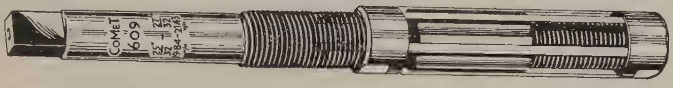

Fig. 311.—The Churchill Adjustable Reamer for Gudgeon-pin Holes and other Automobile Reaming Purposes.

Replacement Pistons for Rebored Cylinders

After the cylinders of a worn engine have been rebored or reground, new pistons are of course required. Whenever possible the oversize pistons supplied by the car-engine manufacturers should be used as these have identical weights to the original pistons and the gudgeon-pin axis is located at exactly the correct distance from the piston crown to provide for the correct compression ratio.

In many instances, however, aluminium-alloy replacement pistons to suit various makes and models of car engines are supplied by certain firms specialising in piston and piston-ring manufacture, e.g. Messrs. Wellworthy, Ltd., Specialloid, Ltd., British Piston Ring Co., Ltd., Hepworth & Grandage, Ltd., etc. These pistons are accurate both in regard to weight and compression-ratio requirements.

In selecting replacement pistons for a reconditioned cylinder block there is a choice of alternative designs of pistons and in coming to a decision in regard to the most suitable type the following are some points to consider:

(1) The aluminium-alloy piston should be designed so that when cold or hot there is no " piston slap " due to clearance for the different expansion of aluminium alloy and cast iron. A plain-skirted piston of parallel form without some form of heat compensation must be given a definite clearance such that, when cold, it tends to promote " piston slap." The modern compensated types, to which reference is made later, do not exhibit this drawback.

(2) Adequate provision for conducting the heat from the hottest portion of the piston, namely, the crown to the gudgeon-pin bosses and skirt, should

be provided; otherwise there may be overheating and a tendency towards detonation.

(3) The lower piston-ring slot should be drilled for the escape of the oil scraped off the cylinder walls by the oil-control ring.

(4) The piston, with its rings and gudgeon pin, i.e. the complete assembly, should be equal in weight to the original piston assembly supplied for the new engine; otherwise the engine balance may be affected and vibration introduced.

(5) The piston should give the same compression ratio as before. This is ensured if the piston crown is of similar form to that of the original piston and the distances between the gudgeon-pin axis and the piston crown (or its highest point) are the same.

Measuring the Piston

Since most modern pistons are oval in section and tapered from the bottom or skirt inwardly to the piston crown, it is usual to express their diameters at some specific position. Thus in the Vauxhall and Bedford pistons the measurement is taken at the top of the piston skirt, just below the ring lands and at right angles to the gudgeon-pin axis. Some manufacturers specify measurements to be taken at a small distance from the bottom of the skirt, i.e. $\frac{1}{4}$ in., and also again at a certain distance from the lower piston land.

Typical Replacement Pistons

As mentioned in the section on cylinder reboring machines, replacement pistons are supplied in definite oversize dimensions to suit cylinders which have been rebored to the same dimensions, i.e. the pistons marked or listed to these oversize diameters will fit rebored cylinders of the same dimensions with the proper clearances.

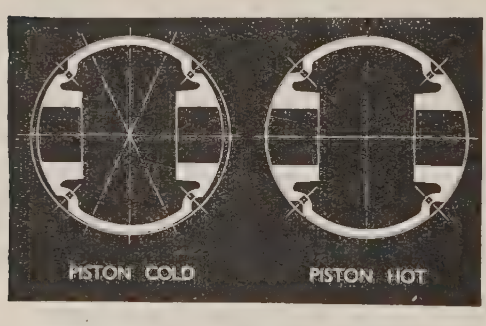

Fig. 312.—Showing the Effect of Expansion on the Heated Aerolite Aluminium Piston. This Compensating Effect eliminates Piston Slap.

A popular type of replacement piston is the oval-ground one, in which the diameter measured in the direction of the gudgeon-pin axis is *smaller* than the diameter across the thrust faces, i.e. at right angles to the former diameter. The thrust-face diameter is a cold sliding fit in the cylinder. When the engine warms up, the heat conducted from the piston crown to the gudgeon-pin bosses and skirt causes a greater expansion of the piston on the gudgeon-pin diameter portion, so that the previously oval piston section then becomes truly circular, with the proper fit in the cylinder. This effect is illustrated in the case of the Aerolite compensation piston in Fig. 312 which shows the oval shape (cold) and the circular shape (when hot). From the sectional view of the piston given in Fig. 312 the manner in which the heat is conducted to the gudgeon-pin boss and its skirt portion is clearly shown. Slots are provided to insulate, and therefore maintain cooler, the thrust-face portions of the piston skirt.

The Wellworthy " Welflex " piston (Fig. 313) is also of the automatic compensating pattern. If the dotted lines are followed, in Fig. 314, it will be seen that the inner ribs, together with a short length of the outer skirt on the thrust side, form an almost continuous ring of metal to a point very close to the actual split, thus ensuring that there is no collapse of the skirt across the thrust and non-thrust areas. In the normal design of split-skirt piston the split ends are unsupported on the whole of the trailing side, namely, from E to E in Fig. 314. In the Welflex piston this area is reduced to a small portion between the ends of the circumferential webs DD. The piston cannot therefore " rock " owing to the skirt closing; neither can the piston rings become convex-faced.

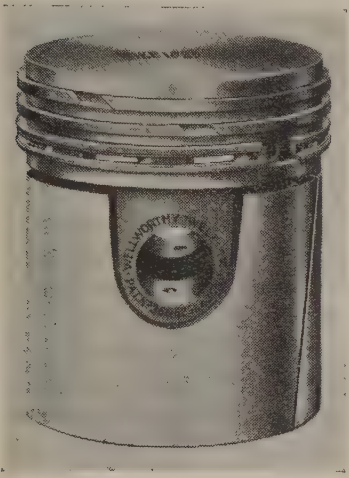

Fig. 313.—The Welflex Piston.

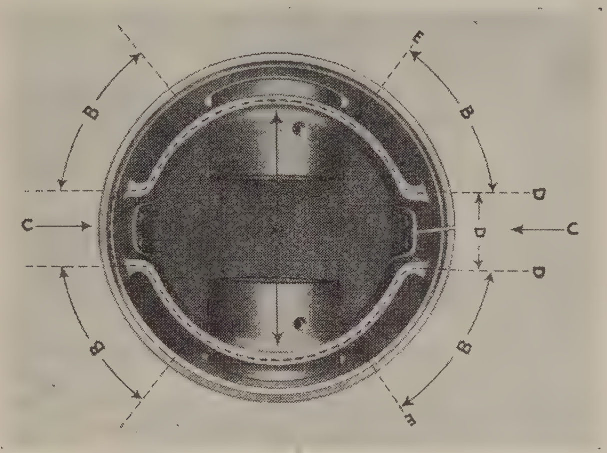

Fig. 314.—Illustrating Compensation Principle of Welflex Piston.

The presence of the split, however, whilst permitting a much smaller clearance than in the normal type of piston, minimises the possibility of seizure due to overdriving in the early stages after a rebore.

The usual tendency of bosses is to expand in an outward direction (as at A). This tends to put the inner circumferential ribs in a state of tension (as at B) and so to pull the outer skirt back from the cylinder wall across the thrust and non-thrust axis of the piston (see C), thus minimising and compensating for expansion and reducing wall pressure.

As a result it is impossible for the piston head to get out of alignment with the skirt and the ring belt remains always true with the bore. The periphery of the ring is therefore at all times in complete contact with the cylinder wall.

An important advantage of the Welflex piston is that it can be fitted with appreciably smaller clearances than those usually employed. Thus, it is only necessary to allow ·00075 in. per inch of piston diameter, e.g. in the case of a 3-in. piston the clearance is only ·00225 in.

The "O.T." piston represents a modern design of oval diamond-turned aluminium-alloy piston that is made for replacement purposes in the case of *particularly "oily" engines*, i.e. those showing appreciable oil consumptions. This piston in addition to two compression and one scraper ring above the gudgeon pin has a second scraper ring located in a groove half-way down the piston skirt. The piston has been proved very effective under test in maintaining power and reducing oil consumption to a marked extent.

For heavy-vehicle engines, including high-speed Diesel engines, the type "C.V." piston shown in Fig. 315 is satisfactory in all respects. It has a circumferential rib supporting the crown, as shown in the two right-hand views. This rib is also continued to the top portion of the gudgeon-pin bosses and serves not only to stiffen the whole upper part of the piston but also to conduct the heat from the crown to the boss regions. The piston is made of oval section with the smaller diameter in the direction of the gudgeon-pin axis. As in the Welflex type of piston the greater heat conduction to the bosses causes the smaller axis portions to expand and the piston to become of circular section at the working temperature. The piston is made of Y-alloy—an exceedingly strong aluminium alloy; it is die-cast and heat-treated to give maximum strength and hardness.

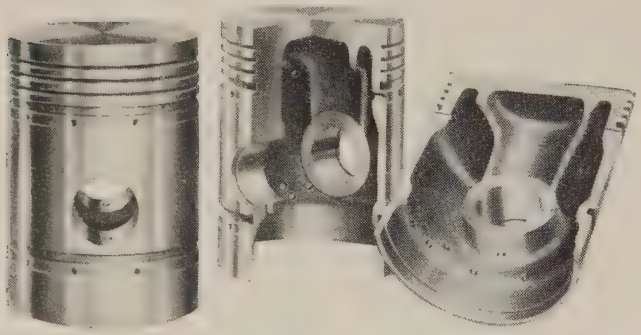

Fig. 315.—The Wellworthy "C.V."-type Piston.

With this design, clearances as low as ·0009 in. per inch of piston diameter will give satisfactory results without risk of seizure. There is no sign of piston slap when cold.

The Specialloid "Easy Start" piston shown in Fig. 316 is another recommended new or replacement piston, giving uniform heat-flow bracing struts from the crown to the gudgeon-pin bosses, strong supports for the crown and off-set cast relief to the portions of the piston skirt around the gudgeon-pin boss region. The skirt is slotted on one of the thrust faces so that it has a slight outward spring action, enabling smaller clearance to be used and obviating piston slap when cold. The slotted-type pistons are tin-plated, a procedure that provides a surface which prevents scruffing when being run in. Further, the soft tin tends to flow round the skirt when in operation, levelling off any uneven surfaces and filling in any scratches left by the boring bar on the cylinder walls. The tin-coated piston is used in certain well-known British and American production car engines, as standard practice, for the reasons stated.

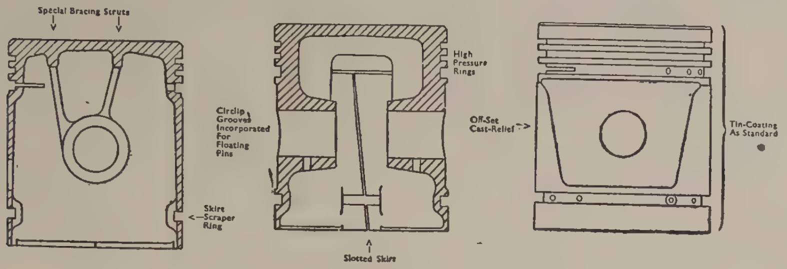

Fig. 316.—The Specialloid " Easy Start " Piston.

A Wire-wound Aluminium Piston

The ordinary split-skirt aluminium piston represents a good compromise whereby the piston can expand as the engine warms up yet does not show any signs of piston slap when cold. As the skirt portion heats up it exerts an increasing pressure along its major axis, which causes friction and a certain loss of power when working temperatures are high. In order to overcome this disadvantage a wire-wound piston, known as the " B.H.B.," which is illustrated in Fig. 317, has been designed. It has a steel-wire band around the upper and lower parts of the piston skirt which resist the expansion of the skirt. The piston therefore remains the same size as the bore—with the desired sliding-fit clearance—at all working temperatures.

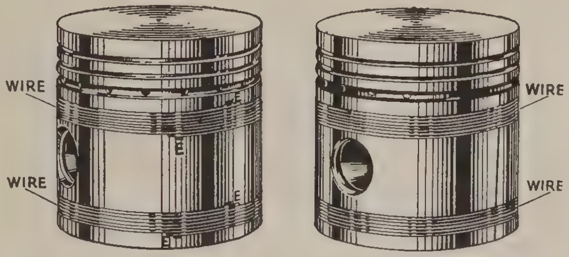

Fig. 317.—The "B.H.B." Wire-wound Aluminium Piston.

The steel wire is wound around a groove machined in the piston skirt both above and below the gudgeon pin. The piston is ground after the wire is in place, so that the bearing surface is of aluminium near the gudgeon pin, whilst elsewhere it is of steel, with grooves corresponding to the turns of the wire. The wire is held in place by spot welding the last two turns to two pieces of similar wire inserted in a small hole broached in the skirt.

The gudgeon pins of these pistons, which are made in a wide range of diameters, are held endwise by circlips.

These pistons are fitted in their cylinders with practically no skirt clearance for sizes up to 3½ in. diameter.

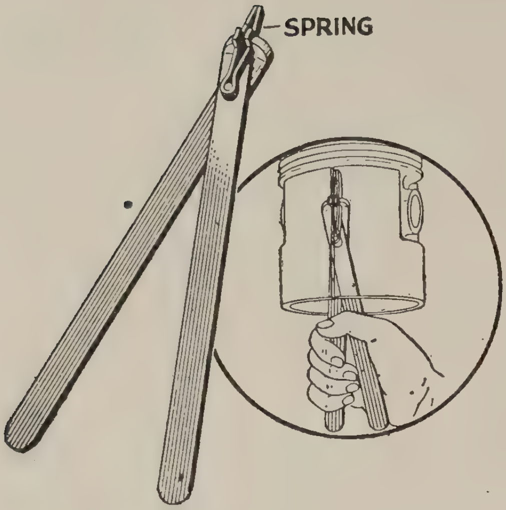

Fig. 318.—The Cords Piston-skirt Expander.

Piston-skirt Expander

In the case of worn split-skirt pistons in engines which have not reached the stage at which reboring has become necessary but only the fitting of new piston rings, the diameter of the skirt can be increased to any desired extent by the Cords device illustrated in Fig. 318. This consists of a "hair-pin-type" spring-steel expanding device having two small projections which fit into a $\frac{1}{4}$-in. diameter hole drilled through the split portion on the same line as the gudgeon-pin axis. The spring is inserted from inside the piston with the aid of the special tool shown in Fig. 318. When in position it cannot become detached; neither can the ends of the projecting lugs score the cylinder walls. To obtain the maximum expansion, the split in the skirt should be wedged outwards before drilling the $\frac{1}{4}$-in. hole. The spring member is very light, and so does not alter appreciably the weight of the piston assembly.

Increasing Diameter of Solid-skirt Pistons

Solid-skirt pistons which have become worn or out of round in the region of the piston skirt can not only be restored to shape but also increased in outside diameter by a commercial method known as "Koetherizing."[1] This method is based upon the same principle as that of hammering the insides of piston rings with a peening hammer in order to expand them, but instead of using a hammer it employs the impact effects of a controlled blast of air and lead shot—similar to a sand-blast.

A vertical arm on the horizontal bracket shown in the illustration holds a jig in the shape of a circle of cast iron with a centre hole of 2-in. diameter on which is placed a pad grooved out to take the piston to be restored.

The shot-blast is directed through a hole in the jig and pad at an angle to the

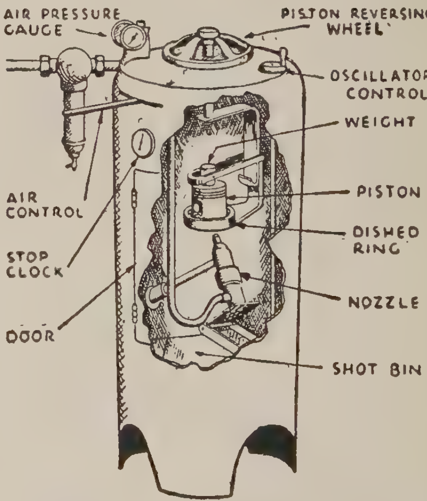

Fig. 319.—The Koetherizing Machine.

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[1] Messrs. Wellworthy, Ltd., Lymington.

gudgeon-pin boss in the interior of the piston. Whilst this is proceeding the piston is arranged to oscillate over a quarter of a circle, and the blast nozzle rises and falls in a semicircular path in such a way that the expansion of the piston skirt (from inside it) is caused mainly on the thrust face.

A pressure of air of 80 lb. per sq. in. is employed and the process occupies only a few seconds. The blasting action on the piston skirt produces a hard skin and alters the shape of the skirt in the manner desired so that the final shape has the correct degree of ovality and taper.

Piston Machining in the Lathe

The method of machining *aluminium pistons* may, perhaps, best be illustrated by the example of solid-skirt pistons described in the *Machinist.* The pistons are cast in individual moulds, and after the gates are sawn off, they go to what is known as a " shimmy " machine, which gives them a regular high-speed shaking or vibratory motion, which effectively jars the sand loose from the castings. A centre projection is cast on the piston head for use in the machining operation.

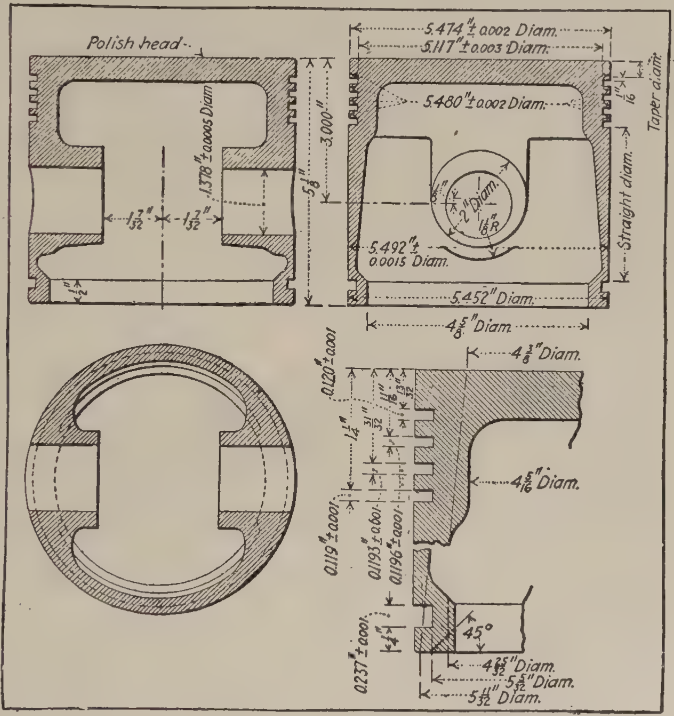

Fig. 320.—Method of making Aluminium-alloy Pistons.

The design of the piston, and the principal dimensions and limits, are shown in Fig. 320.

This illustration gives the main dimensions, and shows the construction of the piston with its grooves for the four narrow rings at the top and a wider or scraper ring at the bottom. It also shows the varying diameters of the piston, the portion above the upper ring being 5·474 in., the three lands 5·480 in. and the diameter at the straight part 5·492 in., while the diameter below the scraper ring is reduced to 5·452 in. The tolerances are also shown in each case, except that of the bottom diameter.

It will be noted that piston-pin boss or hub is $\frac{1}{8}$ in. out of centre instead of being concentric, thus adding to the strength above the pin, so that it can better resist the impact of the explosion.

The first machining operation is to rough turn and bore the skirt (open end), the piston casting being held on an air-operated expansion mandrel; the open end is bored to 4·609 in., with a minus tolerance of ·001 in., and is chamfered to 45°. The small tolerance allowed is because the open end is used for locating the piston in the succeeding operation.

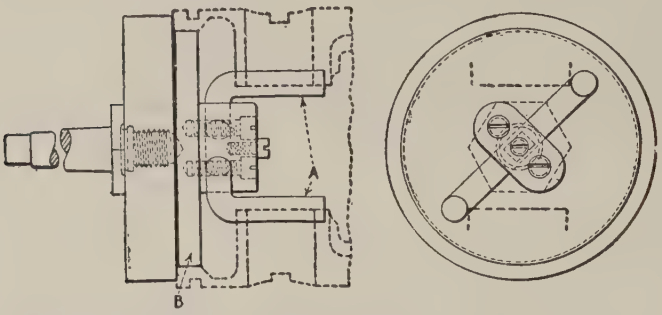

Fig. 321.—Showing a Convenient Method of driving a Piston for Turning Operations.

The piston then goes to the single-spindle drilling machine, where the gudgeon-pin hole is drilled with a $1\frac{9}{32}$-in. drill, and the alignment of the hole checked. The piston is next taken to a Pratt and Witney machine, the piston being held by the pin hole; here the outside diameter is rough turned to 5·452 in., with a plus or minus tolerance of ·005 in., and the piston-ring grooves are roughed out.

The pistons are next tested for strength and homogeneity by a hydraulic testing plant at 160 lb. per sq. in. pressure. They are securely clamped down, with the piston-pin holes plugged, and the pressure applied to the inside.

The ends of the piston bosses are finished in a hand-milling machine. After annealing by heating to 600° F., and cooling in air, the open end is faced and finish bored on a lathe, and the outer corner slightly rounded. The boss on the end is next faced off, the piston being held in a face-plate adapter, and a small centre is drilled and countersunk in the usual manner.

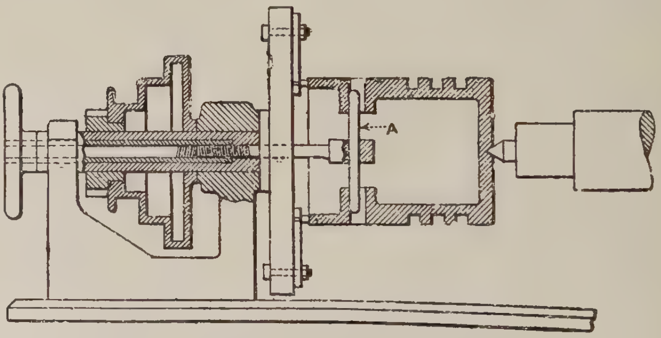

Fig. 322.—Holding Oversize Piston for Machining.

The piston is then finish grooved, and rough and finish ground on a Landis plain grinding machine. Fig. 321 shows the driver used for holding and driving the pistons during the grinding operation. The grinding wheel is of 14-in. diameter by 2-in. width, and is made of "*Crystolon*" of the vitrified type. It is run at 600 to 5,500 ft. per minute, and is lubricated with half paraffin and half lard oil. The piston is again water-tested, and the piston-pin hole finish bored to plus or minus ·0005 in., and to ·003 in. parallelism. The piston is then cleaned, using paraffin and compressed air, weighed, and stamped with its weight; the latter must lie between 4·25 and 4·50 lb.

A convenient method of holding oversize pistons is that shown in Fig. 322. It possesses the advantage over the ordinary chuck method of being free from the liability of distortion. Four pieces of cold-rolled flat steel, each having a short pin projecting from it near one end, are bolted securely to the face plate of the lathe, and a facing cut taken over the exposed ends of the pins to produce a true bearing surface. The long pin A is a loose fit in the head of the drawbolt, the construction of which may easily be seen in the sketch.

With a piston set in place in the lathe and the pin A passed through the wrist-pin holes of the piston and through the head of the drawbolt, the end of the skirt is drawn to a bearing upon the faced ends of the projecting pins with sufficient pressure to drive the piston against the cut, but without any tendency to distort it.

The piston can be trued up quickly by means of a dial indicator, or merely by placing a stick of wood in the toolpost and bringing it to bear lightly against the revolving piston before tightening the hand-wheel nut of the drawbolt. The tail centre of the lathe is then brought up as a safeguard to prevent the piston from being displaced during the turning operation.

Boring the Gudgeon-pin Hole

The method of boring the piston-pin hole illustrated in Figs. 323, 324, and 325 is particularly useful for the garage engineer having a suitable small lathe.

In this case the piston is mounted upon an angle plate on the lathe face-plate, the hole being first drilled, then trued up with single-point boring tool and finally finished with a reamer.

The writer had two pistons of about 3 in. diameter to make with the gudgeon-pin hole about $\frac{5}{8}$ in.

The gudgeon pins were fixed to the connecting rods and ran in the cast-iron pistons.

The turning of the casting was a simple, straightforward work, but boring for the pin looked like being a little more troublesome.

In the first place a suitable size angle plate was not to hand, one was too small and the other too large.

In the second place the pin hole was a few thousandths over $\frac{5}{8}$ in., and a suitable reamer was not available.

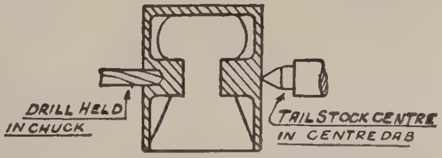

Fig. 323.—Method of Drilling the Gudgeon-pin Holes in the Lathe.

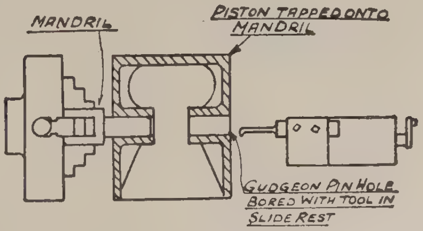
MANDRIL
PISTON TAPPED ONTO MANDRIL
GUDGEON PIN HOLE BORED WITH TOOL IN SLIDE REST

Fig. 324.—Finishing the Holes, using Mandrel held in Self-centring Chuck.

The following procedure was therefore adopted and proved successful.

The pistons were marked off for the holes, the intersection of the lines being carefully marked with a fine centre punch.

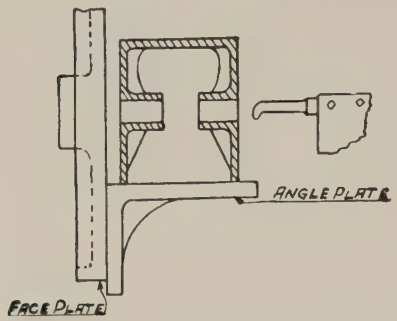

Fig. 325.—Boring the Holes with Piston on Angle Plate.

After marking off, the holes were drilled in the lathe as shown in Fig. 323. The drill was about $\frac{1}{4}$ in. diameter and was made sharp at the point so as to start in the centre dot. After one side had been done the pistons were turned round and the opposite side drilled.

Using the same method the holes were opened out with a pin drill about $\frac{1}{64}$ in. under size.

A piece of mild steel was next chucked and turned down a nice tight fit for the holes now in the pistons (Fig. 324). Without removing from the chuck a piston was pushed on to this mandrel and the hole on the opposite side of the piston bored out with a tool in slide rest and taking fine cuts (Fig. 325). The hole was left tight and finished to size with a small lap.

After the two pistons were done another mandrel was turned, in this case to fit the finished holes and with the pistons on this the other holes were finished.

The holes when finished were absolutely in line.

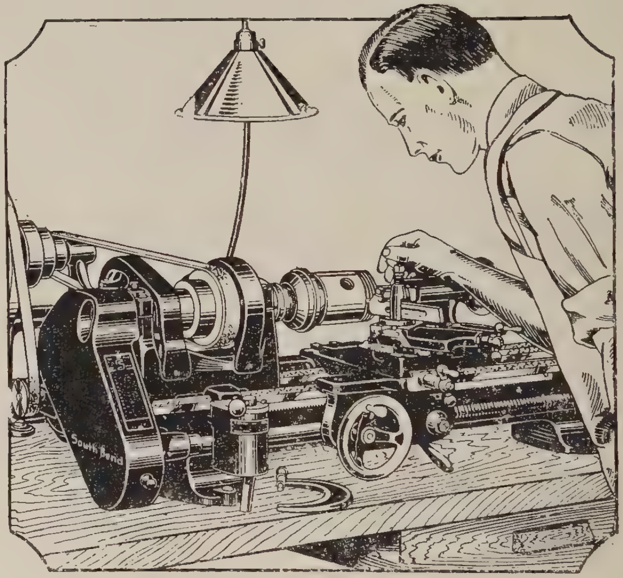

Fig. 326.—Finishing semi-machined Piston on South Bend Lathe.

Finishing Semi-machined Pistons

The following is an outline of the method employed by the South Bend Lathe Works for finishing semi-machined aluminium-alloy pistons. By this method a set of six car-engine-size pistons can be finished, in a lathe of the type mentioned, in thirty minutes; this period includes rough turning, finish turning, and machining the land rings to size. It may be mentioned here that all types of piston, e.g. aluminium, cast-iron, or steel, can be machined in a similar manner to that described. The operations are illustrated and described in their correct sequence.

Mounting Piston in Lathe for Machining

To mount the piston in the lathe for machining, select a cone-adapter ring of the correct diameter to fit into the piston skirt. Adjust the driving dog of the piston adapter so that it will strike the centre of the gudgeon-pin boss, as shown in Fig. 327.

The tailstock spindle should be extended far enough to permit removing the piston and inserting another without changing the position of the tailstock on the lathe bed. Place a drop of oil on the tailstock centre point and adjust the tailstock spindle so that the piston will be held firmly but not too tightly.

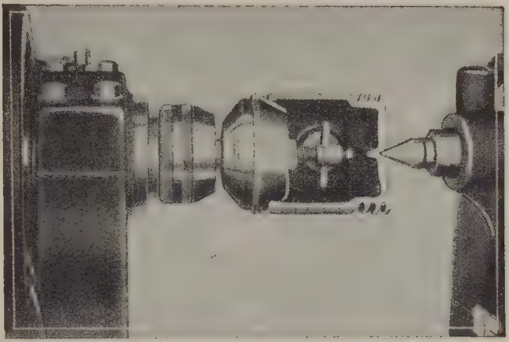

Fig. 327.—Method of driving the Piston for Machining.

Taking a Trial Cut

When the piston is mounted in the lathe, take a light trial cut across its entire length, as shown in Fig. 328, to check the alignment of the centres. Measure the diameter of the piston skirt at each end with a micrometer calliper, as shown in Fig. 329. If one end is smaller in diameter than the other, loosen the tailstock-clamping bolt and adjust the tailstock set-over screws. Continue taking light trial cuts and adjusting set-over screws until the trial cut produces the same diameter at each end of the piston.

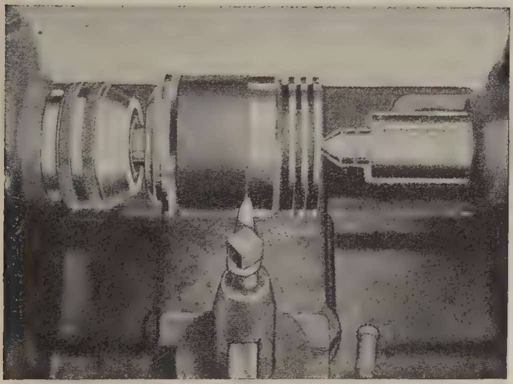

Fig. 328.—Taking a Trial Cut.

Rough-turning the Piston

Before taking the roughing cuts, measure the diameters of the cylinders and calculate the diameter to which each of the pistons is to be machined.

Grind a cutter bit for rough-turning pistons. A Stellite cutter bit is recommended, but a high-speed steel cutter bit will give good results if the lathe-spindle speed is not too fast.

Arrange the lathe carriage for a fairly coarse feed. Use a spindle speed suitable for turning the piston to be machined. Adjust the cutting tool for the first cut.

The roughing cut should be taken over the entire length of each piston in the set without changing position of cutting tool or tailstock. If more than $\frac{1}{8}$ in. is to be removed from diameter of piston, it may be better to take two or more roughing cuts than to remove too much metal in one cut. Allow ·005 in. to ·007 in. on the diameter of the piston for the finishing cut.

Finish-turning the Piston

Before taking the finishing cut, test the inside bevel edge of the piston skirt. If it is not a true circle, ream until it is true. Grind a cutter bit for the finishing cut, and hone the cutting edge with an oil-stone. Use a fine carriage feed in order to produce a smooth finish on the piston skirt.

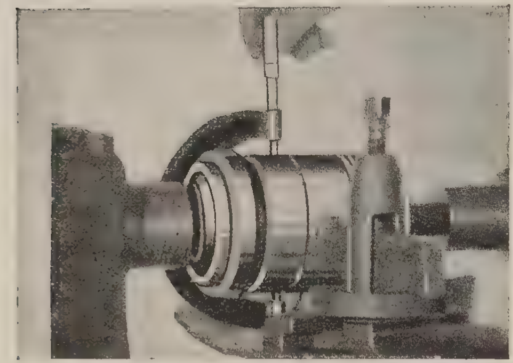
Fig. 329.—Checking the Diameter.

Calculate the clearance so that each piston will be the correct diameter for its own cylinder. Number each piston and the cylinder it is intended to fit. Then take a finishing cut on the top land of the piston. Remove piston from lathe and try the top land (inverted) in its cylinder. Measure the land with a micrometer. After the exact finish-diameter of the piston is determined, finish-turn the skirt of the entire set of pistons without changing position of cutting tool in tool post.

Finish-turning Ring Lands

The piston-ring lands are finished as shown in Fig. 330. Adjust the cutting tool for the correct finished diameter of the top land and turn the top land on each piston of the entire set without changing the adjustment of the tool. Then adjust the cutting tool for the finished diameter of the second land and turn this on each piston in the set. Adjust the tool for the finished diameter of the third land and finish-turn this land on each piston in the set.

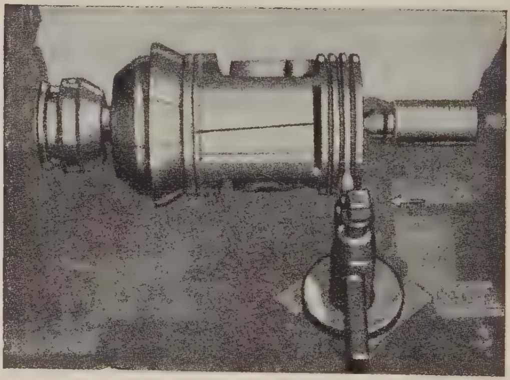
Fig. 330.—Turning the Lands.

Piston Clearances

Although there is a certain diversity of opinion among motor manufacturers regarding the proper clearances to allow between the cylinder and piston, it is possible, as a result of examining a large number of cases, to arrive at an average rule for the clearances.

The latter are, of course, governed not only by the design and material of the piston, but by its diameter being proportional to the latter. The clearances for cast iron are about one-third of those for aluminium-alloy pistons.

It is usual to allow about ·0005 in. to ·001 in. per inch diameter of piston as clearance in the case of cast-iron pistons or cast-iron cylinders.

Thus in the case of a 3-in. piston the clearance will be three times ·00075 in.,[1] that is, ·00225 in.

For aluminium-alloy pistons the average clearance allowed per inch diameter is about ·0017 in., so that a 3-in. piston will have a clearance of ·0051 in. It is considered good practice to provide a greater clearance at the crown or upper portion of the piston, to allow for the higher temperature there. Sometimes the clearance is increased above the gudgeon pin by ·002 in. for each inter-groove portion, to provide for this expansion allowance.

In well-designed aluminium-alloy pistons each land has a special clearance, these clearances being greatest for the top and smallest for the bottom land.

Thus in the case of a three-ring aluminium piston, one well-known engine manufacturer uses the following clearances for pistons of 3-in. diameter:

Top land . . .	·015 in.	clearance
Second land . . .	·012 ,,	,,
Third land . . .	·010 ,,	,,
Fourth land . . .	·060 ,,	,,

The reason for the greater clearance of the fourth land is that the lowest ring is an oil-scraper one. The average clearance of the piston skirt in this case is ·003 in., the skirt being of the diagonal split type.

As we have previously stated, some manufacturers simply make one common allowance for expansion by reducing the piston diameter or lands above the gudgeon pin by ·008 in. to ·010 in. (for a $3\frac{1}{2}$- to 4-in. piston).

The following are the manufacturing clearances allowed on various types and sizes of piston. The manufacturers' names are denoted by letters for a special reason.

Maker.	*Method of Finish of Cylinder.*	*Diameter.*	*Material.*	*Clearance.*
		in.		*in.*
A	Grind	$3\frac{1}{4}$	Aluminium alloy	·005
B	Ream	$2\frac{3}{4}$	,,	·004
C	Grind	3	Cast Iron	·002
D	,,	$3\frac{1}{2}$	,,	·003
E	,,	$4\frac{1}{8}$	,,	·0035
F	,,	$4\frac{1}{2}$	,,	·0035
G	Ream	$3\frac{1}{8}$	,,	·003
H	Grind	$3\frac{1}{2}$	,,	Top ·0045 Bottom ·0030

---

[1] Mean value.

In the case of aluminium-alloy pistons the greater clearance when cold often causes " piston slap," but when the engine warms up this noise ceases. The use of a split skirt or a spring ring at the lower end of the skirt obviates this noise when cold.

It should be mentioned that the more recent aluminium-alloy pistons are heat treated before final machining to size. Diamond tools are often employed for this operation.

Recommended Clearances for Aluminium Pistons

The following are the clearances recommended by the South Bend Lathe Works for split-skirt aluminium-alloy pistons.

Cylinder Bore. in.	2½ *to* 3 *in.*	3 *to* 3½ *in.*	3½ *to* 4 *in.*	4 *to* 4½ *in.*	4½ *to* 5 *in.*
Top land	·019 in.	·023 in.	·028 in.	·034 in.	·040 in.
Second land	·014 in.	·016 in.	·019 in.	·023 in.	·027 in.
Third land	·014 in.	·016 in.	·019 in.	·023 in.	·027 in.
Oil land[1]	$\frac{1}{32}$ in. less than standard cylinder bore.				
Skirt	·002 in.	·002¼ in.	·002½ in.	·003 in.	·003¼ in.

[1] The land below third piston scraper ring.

Curing Oil-pumping Pistons

Many engines are notable for their poor oil economy, and although excessive oil consumption is often a sign of leaky rings and worn pistons, yet there are cases of bad piston design causing this.

Some pistons when working tend to scrape the oil off the cylinder walls so as to leave a surplus at the upper end of the piston; this oil is burnt or carbonised during the firing stroke.

Not only do such pistons cause excessive oil consumption, but the cylinders carbon up more rapidly.

Sometimes, as in the case of the back cylinder of a V-twin engine or an end cylinder of a four-cylinder model, one cylinder gets more oil than the others, usually through bad oil-distribution arrangements, with a result that one cylinder carbonises to a greater extent than another, and the engine has to be decarbonised much sooner than it normally should.

One has occasionally cured cases of bad oil distribution in old engines by turning an oblique flat on the lower side of the piston-ring groove, and drilling a series of small holes, about $\frac{1}{16}$-in. diameter, in the slanting surface. The bottom ring then acts as a scraper on the down-stroke of the piston, and the oil thus scraped finds its way to the inside of the piston, and therefore does not remain on the cylinder walls. In particularly bad cases, a second similar oil groove may be made on the lower edge of the second, or middle, piston ring; when there is a floating gudgeon pin, *the surplus oil scraped off* the walls may be led through holes drilled obliquely from the oblique groove to the piston bosses, so as to lubricate the pins. It is, however, advisable to fit oil-scraper rings if the correct sizes can be obtained.

When using *oil-scraper and compound piston rings*, such as the "Clupet" and "Superoyl," in cases of oil pumping, the fact must not be overlooked that if there is an excessive clearance between the piston and the cylinder, the use of bevelled piston grooves, scraper, and special piston rings is only a temporary and partially effective remedy; regrinding of the cylinders and fitting new pistons is the only positive cure in such cases.

Mention should be also made of the Wellworthy Simplex and Duaflex self-adjusting piston rings as a remedy for oil-pumping pistons.

Turning Split-skirt Pistons

When aluminium pistons of the split-skirt pattern have to be reduced in diameter or trued up in order to fit smaller sizes of cylinder barrel or cylinder sleeves, it is advisable to solder the end of the split, in order to prevent chattering of the tool and imperfect finish. Fig. 331 shows just where the solder should be applied. Suitable aluminium solders, such as "Alunize" (the use of which is described elsewhere in this work), are available for this purpose.

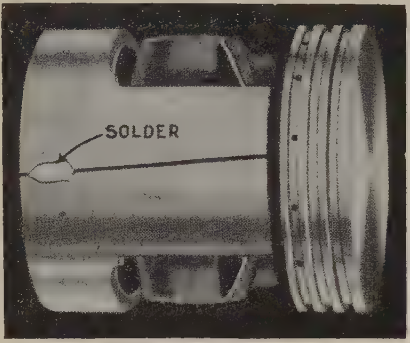

Fig. 331.

Position of Split in Split-skirt Pistons

In the case of split-skirt pistons when these are assembled in the cylinder barrels the *plain unsplit side* should be on the side which takes the piston thrust on the firing stroke, i.e. it should be fitted towards the off-side of the car in the usual case of an engine running in a clockwise direction as viewed from the front of the car. It is perhaps better to remember that the *split side* of the piston skirt should be on the *near-side*, i.e. the minimum thrust side.

Machining Aluminium Alloys

When turning aluminium alloys, such as those used for pistons, a moderately high speed should be employed and the tools should have acute cutting edges.

It is advisable to finish sharpening all tools on an oil-stone in order to get the required keen edges. When boring or turning, a pointed tool with a large top clearance should be used. The lubricant plays an important part when machining these alloys. For general work *paraffin oil* is much used. *Turpentine* is also recommended by some authorities, but this is not suitable when tapping or screwing, as the liquid leaves a resinous deposit.

When *drilling or tapping* aluminium alloys, beeswax rubbed on the drill, or tap, is preferred as a lubricant by many machinists. When *turning* these alloys, it is recommended that tools should have a clearance angle of about 20° and a top rake of 40° for the softer alloys, rising to 30° for the harder ones.

Provided that the work is of a rigid nature the roughing cut can be a deep one. As much as ¼ in. to $\frac{5}{16}$ in. is sometimes taken off in one cut when running at a speed of 300 to 400 ft. per min.

A lubricant should be used for a heavy cut of this nature, although lighter roughing cuts are sometimes done dry.

A speed of 600 to 800 ft. per min. may be used for finishing cuts when using ordinary carbon-steel tools. For high-speed tool steel the speed may be higher.

To obtain a good surface use a very light cut and a slow feed. A lubricant should always be used for finishing cuts; a mixture of paraffin oil and lard oil, or rape oil, in equal quantities will give good results with most aluminium alloys. The lubricant should be used under pressure and should be fed so that it tends to clear away the turnings from the work.

Ordinary screw-cutting tools, *dies*, and *taps* can be used satisfactorily for aluminium alloys. A good plan is to employ a lathe screw-cutting tool first, and finish with a chaser, using paraffin oil as a lubricant.

Special taps are now sold for aluminium work; these give a better cutting action than ordinary taps.

For filing aluminium and its alloys single-cut files should always be used. Files of the double-cut type clog rapidly and become useless.

A quick method of *cleaning clogged files* is to dip them in strong caustic-soda solution for a moment, after which the metal particles can be wiped off easily. A wash in hot water and a drying in sawdust will prevent the metal from rusting after this treatment.

For sawing aluminium a band saw of the wood-working type is excellent for such work as cutting off runners and rises from castings. The teeth should be large and the speed about 600 ft. per min.

Hand cutting and trimming of thin sheet is easily done with a woodworker's tenon saw and jack plane. Greater thicknesses may be cut rapidly with a coarse hacksaw.

In *milling aluminium alloys* it is important to use tools in which the teeth are set farther apart than usual, so as to avoid clogging of the metal particles. A stream of soapy water directed on to the cutter will obviate any tendency to clog by washing away the particles as they are formed.

Where a bright finish is required paraffin should be used as a lubricant. In the ordinary way, however, when a mirror-like finish is not required, milling may be performed dry.

For *drilling aluminium alloys* standard twist drills are quite satisfactory, although the use of flat drills is sometimes advocated. The same precautions regarding keen edges apply to drills as to turning tools. Aluminium should be drilled at a high speed, but with only a moderate feed. The best peripheral speed is from 150 to 200 ft. per min.; thus, in the case of a drill of ¼-in. diameter the speed should be about 2,400 r.p.m. With a 1-in. drill the speed would be about 600 r.p.m., and the feed about ·005 in. per revolution; for a ½-in. drill the corresponding figure is ·003 in. Paraffin is a good lubricant when drilling.

Tools Used for Piston Turning

The following is an account of the tools used for turning aluminium-alloy pistons and the methods of sharpening these, as recommended by the South Bend Lathe Works.

High-speed Steel and Stellite Cutter Tools

High-speed steel cutter bits, which are held in a tool holder as shown in Fig. 332, are usually used for turning pistons, but some shops prefer Stellite cutter bits, as they will hold a cutting edge longer than high-speed steel cutter bits.

Fig. 333 shows the dimensions and angles of high-speed steel and Stellite cutter bits for use in a standard lathe tool holder. The point of the cutter bit is ground to a $\frac{1}{32}$-in. radius.

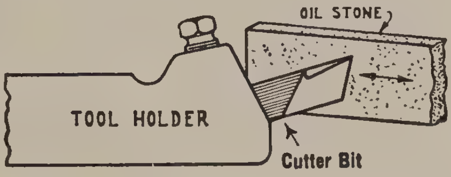

Fig. 332.

Home Cutting Edge for Finishing

Always hone the cutting edge of the cutter bit before using it for finishing pistons. Honing to a keen edge lengthens the life of the cutter bit and produces a much smoother finish on the surface of the piston. It is advisable to hone the cutting edge of the roughing tool as well as the finishing tool (Fig. 332).

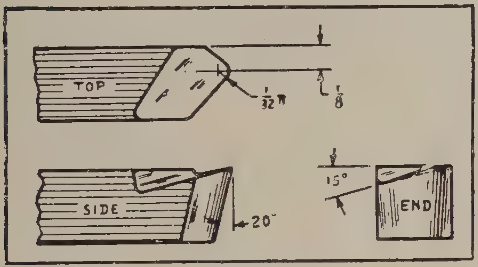

Fig. 333.

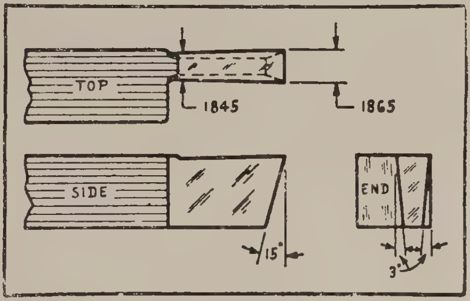

Fig. 334.

Cutter Bit for Widening Piston-ring Grooves

Fig. 334 shows a cutter bit ground for widening piston-ring grooves. The point of the cutter bit is two-thousandths of an inch wider than the back of the cutter bit, and there is clearance on both sides. Feed the cutter bit straight in. If it is ground to the correct width, the groove may be widened in one cut.

Some mechanics prefer to use a side cutter bit with a narrow point for widening ring grooves. Only one side of the groove is machined at a time when this method is used.

Tungsten-carbide-tipped Tools for Piston Finishing

If an unusually smooth bright finish is desired on the piston, a tungsten-carbide-tipped cutter, which is held in a tool holder as shown in Fig. 332, may be used. Figs. 335 and 336 show the shape of cutting edge of the bit and method of using the tool, respectively.

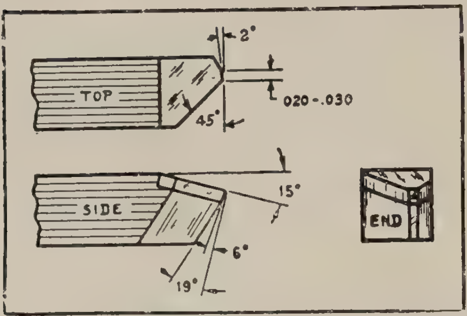

Fig. 335.—Shape of Tungsten-carbide-tipped Tool.

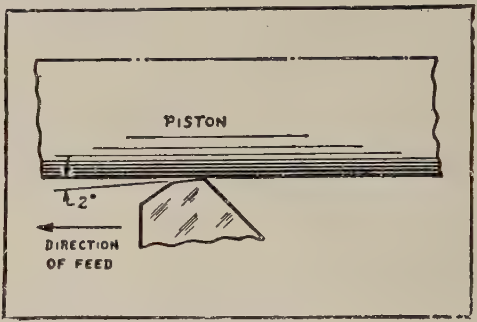

Fig. 336.—Method of using Tool shown in Fig. 335.

Tungsten-carbide-tipped cutter bits should not be sharpened on an ordinary grinding wheel, but should be lapped on a cast-iron lapping disc impregnated with diamond dust.

Turning Speeds for Piston Metals, etc.

The following table shows the recommended spindle speeds for turning various kinds of metals. The spindle speeds listed in the second column should be used for machining cast-iron pistons, and the last column gives the spindle speeds recommended for turning aluminium-alloy pistons.

This table is based on average working conditions. Finishing cuts may sometimes be taken at slightly higher speeds, and slower speeds may produce better results on heavy roughing cuts.

When rough-turning, use a coarse feed and take as many cuts as are required to reduce the work nearly to the finished size. When finish-turning, use a very fine feed and remove ·005 in. to ·007 in. or less from the diameter in one cut.

TABLE OF TURNING SPEEDS

Diameter of Work, in.	*Revolutions per Minute.*			
	Cast Iron, 60 *F.P.M.*	*Mild Steel,* 90 *F.P.M.*	*Brass,* 150 *F.P.M.*	*Aluminium,* 200 *F.P.M.*
1	229	344	573	764
1½	153	229	382	510
2	115	172	287	382
2½	92	138	229	306
3	76	115	191	254
3½	65	98	164	218
4	57	86	143	191
5	46	69	115	153

F.P.M. = Feet per minute at tool point.

CHAPTER 10

THE CONNECTING ROD AND MAIN BEARINGS

The General Crankshaft Assembly

Before undertaking the actual dismantling and subsequent overhaul of the connecting rod and main bearings, it is advisable for the mechanic to have a sound knowledge of the various components concerned and their locations, fits, etc., in the engine. In this connection a close study of the crankshaft and oil-sump assembly, a typical example of which is given in Fig. 337, will well repay the time spent. In particular, attention is here drawn to the crankshaft (5), and its main bearings (7), (8), (9), (17), (18), (19), and (21), as these components will be dealt with in the present chapter.

The Connecting Rod

There are three principal operations that concern the connecting rod, and which may have to be undertaken when repairing or thoroughly overhauling automobile engines. These operations are as follows: namely (1) renewal of small-end bush; (2) adjustment relining or replacement of big-end bearings, and (3) alignment of the connecting-rod bearings.

If the connecting-rod small-end carries the gudgeon pin, as in the case of the Ford, Austin, and Morris designs, the first operation is, of course, dispensed with, but instead the piston bosses may require rebushing.

Testing Connecting-rod Bearings for Wear

A method of ascertaining whether there is any appreciable amount of wear in the connecting-rod bearings is to place the piston of the particular cylinder under consideration on its top dead centre and then employ a strong suction washer mounted on a handle. The handle is alternately pressed downwards and then pulled upwards, and if there is any play in the bearings this will at once be shown by the difference in the readings of a dial gauge mounted over the piston (Fig. 338). The dial gauge should be fixed to a bracket, scribing-block, or similar object so that it is quite rigid.

A convenient method of holding a dial gauge for this and many other similar purposes is shown in Fig. 339. The apparatus in question is that

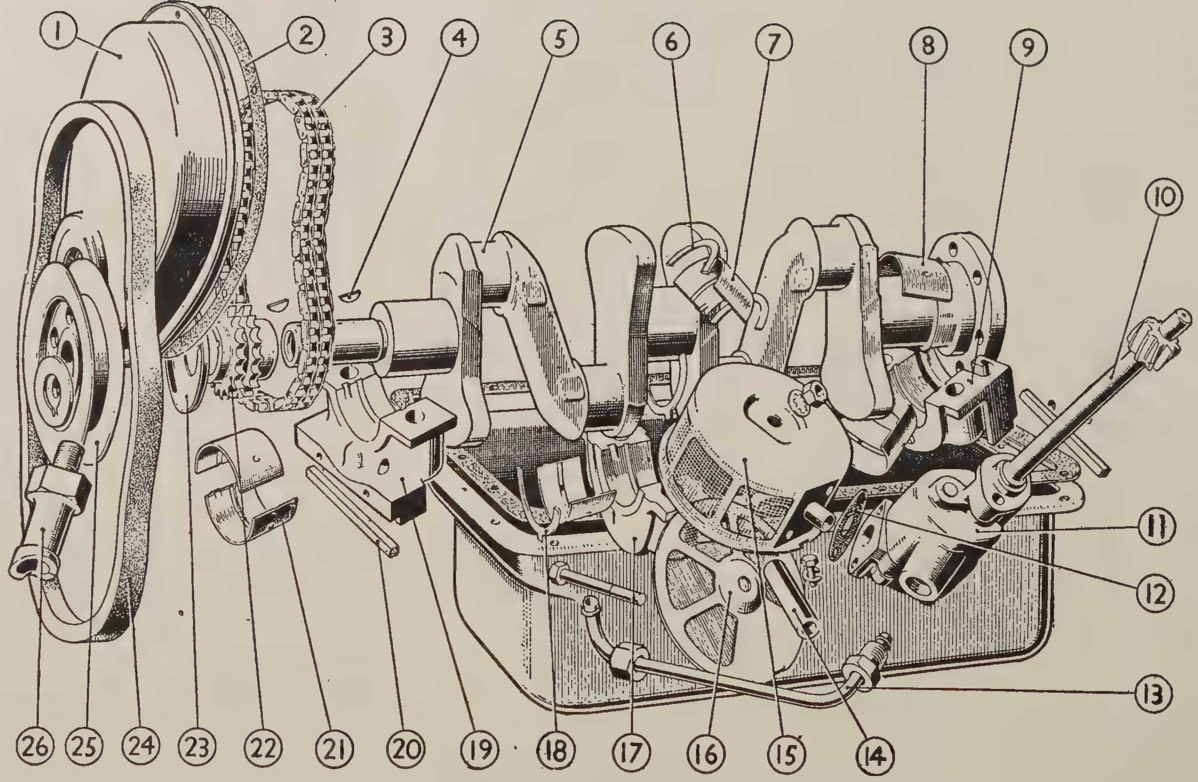

Fig. 337.—The Austin A40 Crankshaft and Main Bearings Assembly.

1. Timing Cover. 2. Joint Washer. 3. Timing Chain. 4. Crankshaft Keys. 5. Crankshaft. 6. Thrust Washer. 7. Centre Main Bearing. 8. Rear Main Bearing. 9. Rear Main Bearing Cap. 10. Oil-pump Spindle. 11. Oil Pump. 12. Joint Washer. 13. Oil-delivery Pipe. 14. Distance Piece. 15. Strainer Body. 16. Strainer Cover. 17. Centre Main Bearing Cap. 18. Thrust Washer. 19. Front Main Bearing Cap. 20. Cork Strips. 21. Front Main Bearing. 22. Crankshaft Gear. 23. Oil Thrower. 24. Fan Belt. 25. Fan Pulley. 26. Starting Nut.

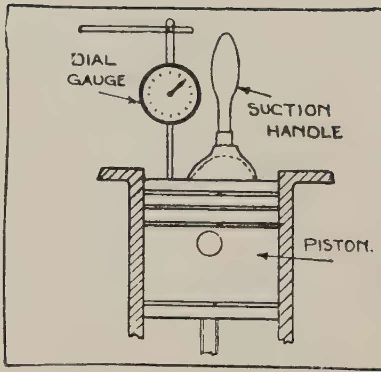

Fig. 338.—Testing the Connecting-ro
Bearings for Wear.

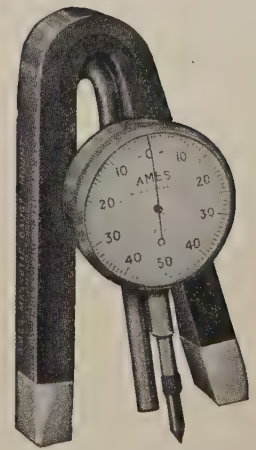

Fig. 339.—The Ames Magnetic Gauge Mount.

known as the Ames Magnetic Gauge Mount. It consists of a powerful horse-shoe magnet carrying a rod on which the gauge can slide; the gauge can be locked in any position along this rod.

The poles, forming the feet of the magnet, will hold securely on to any steel or cast-iron part.

Fig. 340 illustrates the use of the gauge for testing connecting-rod bearings by the method we have already described. The same arrangement can also be employed *for ascertaining the top dead centre position.*

Fig. 341 shows how the magnetic gauge mount is used for testing pistons for wear in the gudgeon-pin bearing. In this case the connecting rod is clamped in the small vice shown, and the piston is pushed in a backwards and forwards direction; if there is any play in the bearing this will at once be shown by the gauge.

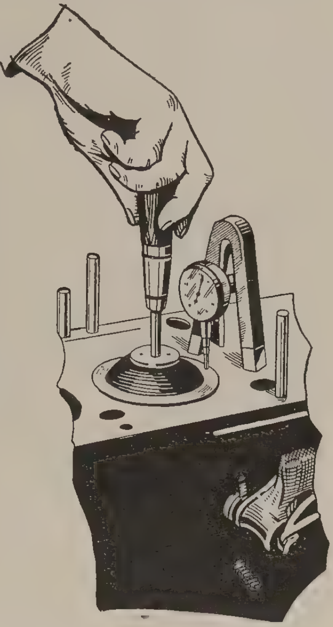

Fig. 340.—Showing Method of using Ames Gauge for testing Connecting-rod Bearings.

Small-end Bushes

After a considerable period of running, say 25,000 to 35,000 miles, the small-end bush may wear oval, due to the more or less vertical thrust of the connecting rod, and if any appreciable clearance, say ·010 in. to ·015 in., occurs, this will cause a knock to be heard in the engine; we have already indicated how such a knock may be located.

If, after dismantling, thoroughly cleaning, and replacing the gudgeon pin in the small end, the former has any appreciable rock, it is a sign of excessive wear. The pin and bearing should be gauged in several places. Sometimes part of the wear occurs in the bush and part on the gudgeon pin; indeed, it is quite common to find an appreciable amount of wear on the pin. When a new bush is fitted, it is important to ascertain that the pin is quite uniform; otherwise the bush will fit those parts (the ends) which go into the piston bosses but will be a slack fit on the central portion.

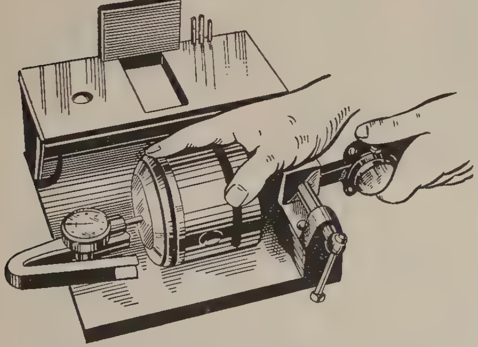

Fig. 341.—Illustrating Method of testing Pistons for Wear in Gudgeon-pin Bearings.

The only remedy in such cases is a new gudgeon pin and a new bush.

A Practical Method for Taking Up Wear

If the gudgeon pin is not worn appreciably, but there is a slight play in the bush, this can be taken up in the following way: Drive or force out the bush, tin or solder the outside surface, and force the bush home again into the connecting-rod eye. The effect of the soldering is to increase the diameter of the bush, so that when it is forced back again it will close up slightly and become a better fit on the pin; this method will often obviate making a new bush. It may, however, be necessary to scrape the bush so that the pin bears evenly all along.

Reaming and Honing

If a new gudgeon pin is to be made, the old small-end bush can be used again by simply reaming the piston boss holes and the small-end bush (in place), and since the gudgeon pin is usually a driving fit in the piston bosses, the small-end bush must be scraped or reamed out to give the bearing fit required.

Gudgeon-pin holes, as previously explained, can also be honed in the lathe by holding the reamer in a self-centring chuck or collet, and manipulating the piston by hand, as shown in Fig. 310 on p. 251. With long reamers it is advisable to have the tailstock centre as a support for the other end.

Fitting by Drifting the Hole

An effective method of obtaining a good-fitting gudgeon pin with a perfectly smooth bearing surface in the small-end bush is to use a slightly oversize gudgeon pin as a drift. The pin is hammered through the bush, when it leaves a good burnished surface and the proper clearance for working.

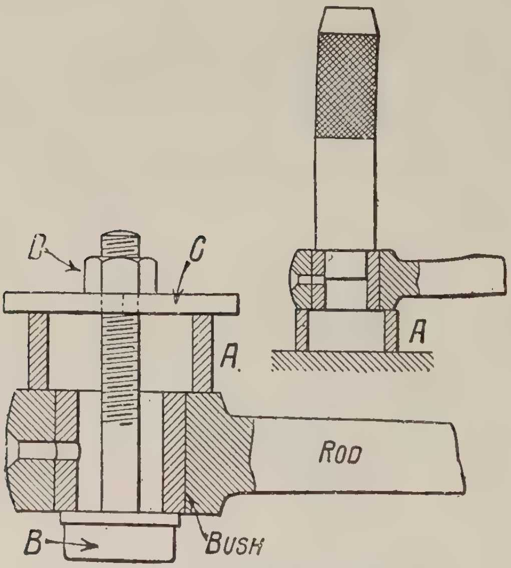

Fig. 342.—Showing how the Connecting-rod Bushes are withdrawn.

Notes on Fitting New Bushes

When the old bush has to be removed, it can either be punched out or withdrawn with a bolt-and-nut device, as shown in Fig. 342. The bolt shown has a head, B, slightly smaller than the outside diameter of the bush. A piece of tube, A, of internal diameter larger than the outside diameter of the bush, is used to allow the latter to pass into it unobstructed when the nut D is tightened on the washer C.

The upper inset sketch in Fig. 342 illustrates a convenient form of punch, having a shouldered head, for punching out small-end bushes. Here, again, it is necessary to use a larger bush or piece of tube, A, to allow the bush to clear as it comes out.

When making new small-end bushes, phosphor-bronze or gun-metal should be employed; the material should be free from sand-markings or blowholes.

The inside diameter of the bush should be slightly larger by about ·001 in. to ·002 in. than the bearing limit, to allow for the closing in when the bush is forced into the eye of the connecting rod; otherwise the bush will have to be honed or reamered out afterwards. For correct "running" and "force" fit allowances, the reader should consult pocket-books of mechanical engineering, or use the British Standards Limits and Fits, published by the British Standards Institution, 28 Victoria St., London, S.W.1. The Newall Standards, given in most engineering pocket books, have also been widely used for this purpose.

It is better practice to force the new bush into the connecting rod by a steady screw or hydraulic pressure than to hammer it in.

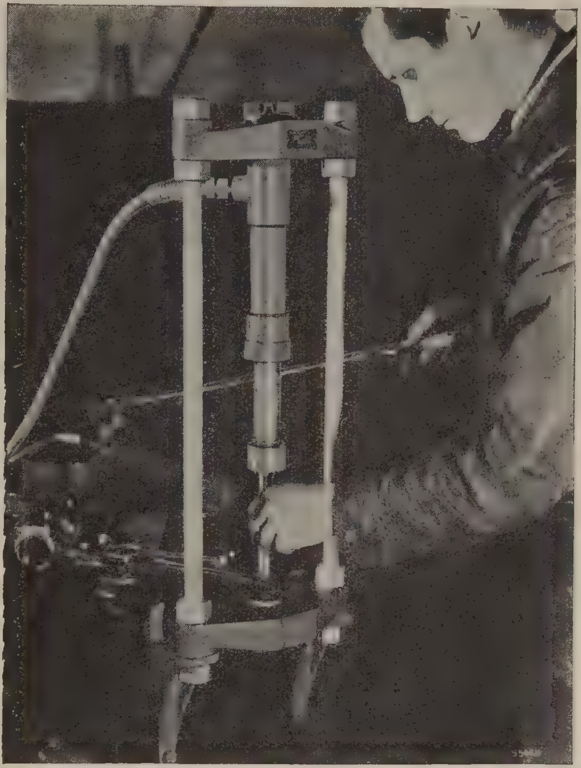

Fig. 343.—Showing the Porto Power Press used for inserting new Small-end Bushes.

Special presses for this purpose are now supplied by garage equipment firms.

The Porto Press, described earlier in this volume, is another convenient device for forcing small-end bushes out of their connecting rods, or for inserting new bushes.

The device in question is provided with a special stand for this purpose. Fig. 343 illustrates the press as set up for forcing out connecting-rod bushes. It will be observed that the distance between the press ram and its anvil below can be adjusted by means of the screwed column supports and their nuts.

Owing also to the large number of hardened sleeves and bearings, such as ball-races, bushes, etc., used in the construction of a motor-car, it is advisable to install in the repair shop a lever-type press. A tool of this description is well worth while, because it prevents to a large extent the abuse of delicate and expensive parts by hammering, which, unfortunately, is the favourite method of many mechanics. The M.E. Press, shown in Fig. 344, is a simple and suitable machine which has been designed to meet the needs of the average type of shop, and consists of a heavy-type base fitted with a revolving slotted pressure pad. The head of the press consists of a powerful lever ratchet operating a spur pinion and vertical pressure rack, and is capable of exerting a steady pressure of approximately 3 tons load. The special feature of the lever-type press is that it is very sensitive, and the movement of the part being operated upon can be felt, thus preventing undue strain and damage. The press, being of the pillar type and open at all sides, allows for odd-shaped parts to be handled.

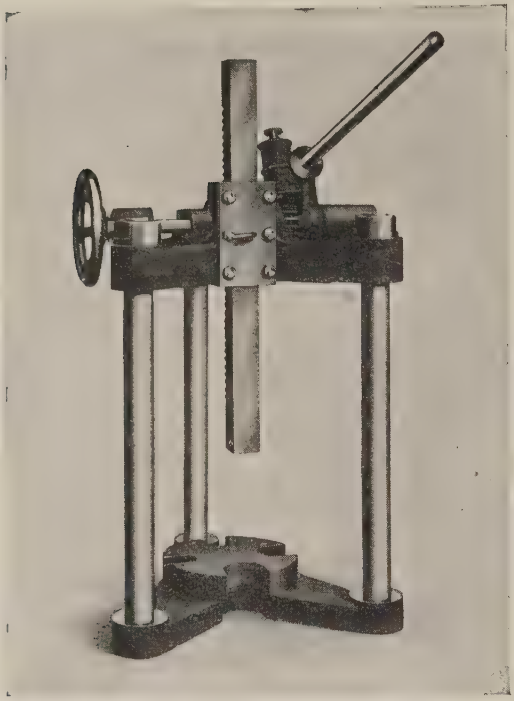
Fig. 344.—The M.E. Garage Press.

When replacing a new bush in the connecting rod, it is better to *drill the oil hole* after fitting, as it is not always possible to force the bush into position so that the hole coincides with the one in the connecting rod. Similarly the oil leads, or grooves, from the oil hole should be cut out (with a small round-nosed chisel) afterwards, but some care is required in removing, by scraping, all burrs.

Lining Up and Straightening Connecting Rods

It is important to ensure that the axes of the small- and big-end bearings are exactly parallel the one with the other; otherwise there will be excessive wear on these bearings and increased friction as well. Occasionally, when an engine is taken down, the connecting rod is accidently bent—it may be due to driving a tight gudgeon pin out with the connecting rod held or clamped in a vice. Sometimes after a rod has been rebushed or re-metalled it will become twisted slightly. Whatever the cause, there is no doubt that now and again bent and twisted rods do occur, and that if the defect is not detected an appreciable loss of power, together with fairly rapid wear of the bearings, occur.

The fault mentioned is sufficiently general for several large firms of motor accessory dealers to provide special connecting-rod alignment jigs and fixtures.

A good practical method of detecting a bent or twisted rod is illustrated in Fig. 345. Two turned rods, G and H (1), are employed. The former is a push fit in the small-end and the latter in the big-end. The rods need not, however, be push fits, but can be of any convenient diameters, and allowed to rest in the bottoms of the bearings. It is better, however, to use good-fitting rods, as the measurements taken may otherwise disturb them. Small rods with split-bush adapters to fit the bearings can be employed, as shown at F (2). To detect any side bending, the distances, D, between the ends of the rods G and H (1) are measured; for parallelism these two distances should, of course, be the same.

Bending in the other direction, or plane of the rod, is not serious, as the bearings remain parallel, and a microscopic shortening of the rod only occurs; it can usually be detected by sighting down the top of the rod.

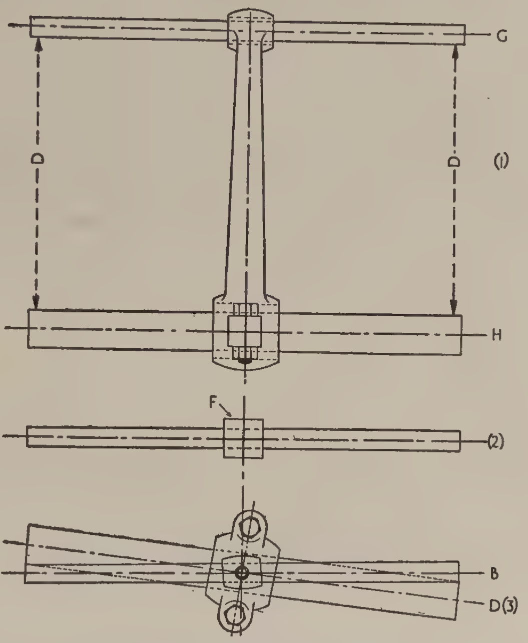

Fig. 345.—Showing Methods for checking Alignment and Twisting of Connecting Rods.

To detect twisting of the connecting rod, the latter should be viewed from the small-end, with the rods G and H (Fig. 345 (3)), in position. Any slight degree of twisting can at once be detected by the lack of parallelism of the two axes AB and CD respectively.

This method is a sound one, and has been much used in engineering shops. The rod can, of course, be mounted on blocks on a marking-off table, and tested with a dial gauge or feelers.

Referring next to the standard connecting-rod alignment devices, these generally use a flat surface, provided with pins at right angles to take either the big- or small-end bearings. The piston is assembled on the small-end and the side of the piston tested for alignment against the flat surface mentioned.

Fig. 346 illustrates a typical connecting-rod aligner which can be used for rods of various sizes.

A mandrel is fitted to the big-end bearing, either directly or with the aid of a split bush; the mandrel rests in V-notches on the base member. A mandrel is also inserted in the small-end, and the parallelism of this with the big-end one is checked against the machined surfaces of a special sliding block which moves in a V-groove in the base member. The error in both directions is indicated by this device. The block, which is provided with gauging surfaces to show error in both directions, slides in the accurately machined V mentioned, and is kept in contact at all times by means of a spring, thereby maintaining the truth of the tool under all conditions. The outfit supplied includes a $1\frac{1}{4}$-in. ground mandrel, and three split bushes—$1\frac{3}{8}$, $1\frac{1}{2}$, and $1\frac{5}{8}$ in.

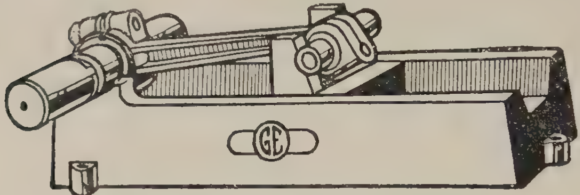

Fig. 346.—Connecting-rod Aligning Device.

The "Millennium" connecting-rod aligner, which is particularly designed for Morris engines, is illustrated in Fig. 347. There is the usual big-end mandrel, and in addition two accurately machined surfaces, one above and one below, both horizontal, so that the alignment of the rod, as gauged by the small-end mandrel, can be tested in two directions at right angles. If the small end of the rod does not occupy a central position in the slotted portion of each machined surface, non-alignment is indicated.

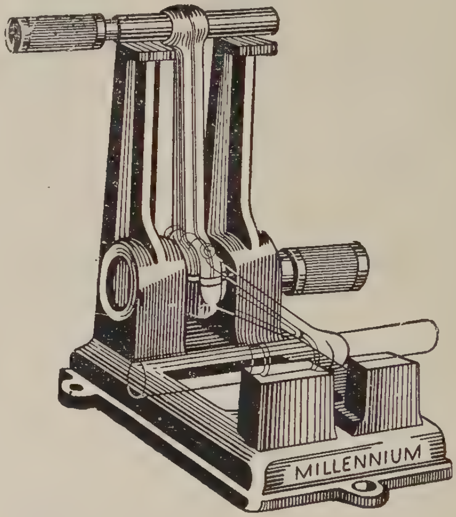

Fig. 347.—The "Millennium" Connecting-rod Aligner.

Another modern development of the ordinary connecting-rod alignment testing machine, which measures the bending and twist effect, is the Buma Roto-V-Test, which is based upon the accepted principles of testing the alignment by means of mandrels, parallel bars, and V-rests. This machine, which also combines the means of correcting for any bending or twist errors, is described later in this section.

Another well-designed connecting-rod aligning jig is that made by Messrs. Boneham & Turner, Ltd., Mansfield, and illustrated in Figs. 348 and 349. By means of this jig the piston and rod take up the same position as when assembled in the engine. The piston has two testing faces, the top surfaces of these being used for gudgeon-pin alignment tests.

Fig. 349 shows a piston and connecting rod in position on the jig. The mandrel takes the place of the crankshaft and is laid across the two V-blocks. The piston lies between two sliding faces which are perfectly parallel and square and thus correspond to the cylinder walls. The piston

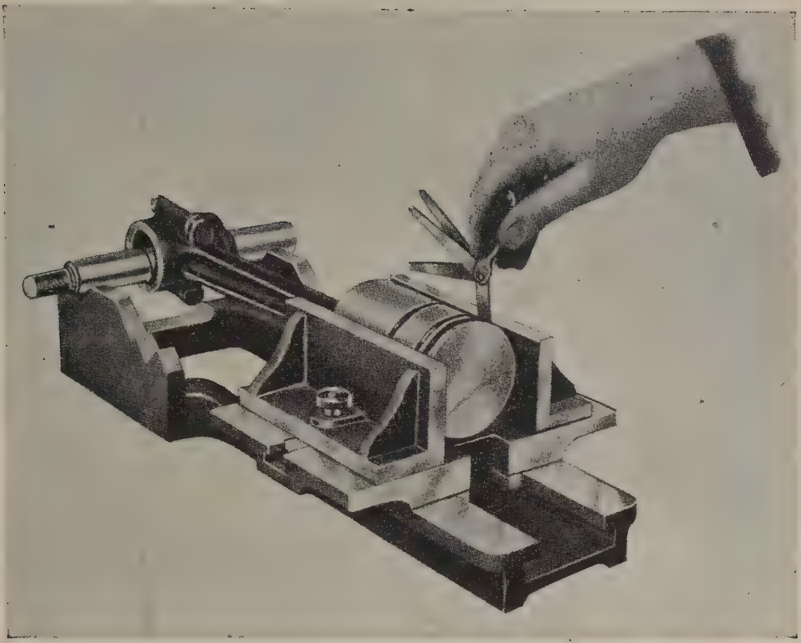

Fig. 348.—Testing Connecting Rod for Bending.

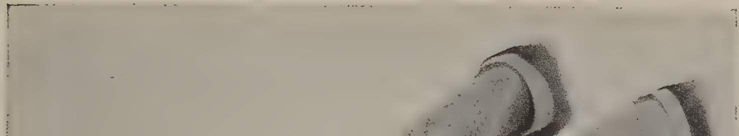

Fig. 349.—Checking the Connecting Rod for Twist.

and connecting rod thus take up *exactly* the same position as when assembled in the engine and any deviation from truth can easily be checked with a feeler gauge and corrected. Taper and oval-turned or pistons with relieved sides can be checked equally well.

Fig. 349 illustrates the connecting rod being checked for twist. The set-up is exactly as before except that the pin is laid on top of the parallel plates, which are dead accurate and square with V-blocks. This enables the pin to be checked for any twist by actual sighting, touch, or with a feeler gauge.

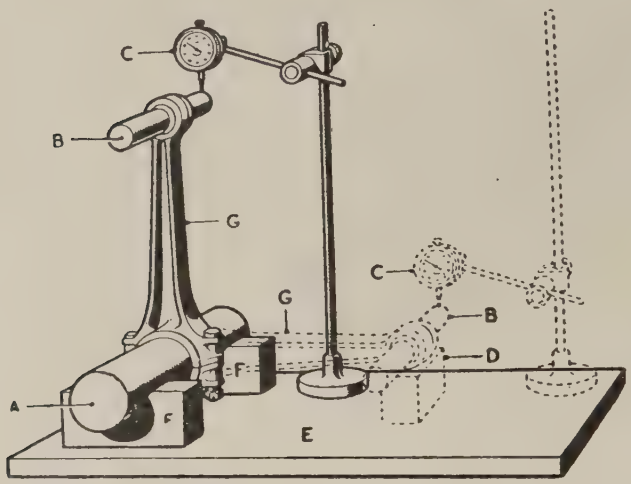

Fig. 350.—Another Connecting-rod Checking Method.

Connecting-rod Straighteners

Although it is not a difficult matter for the average mechanic to straighten a bent or twisted connecting rod, yet it is possible to locally distort and mark it in the vice or with the hammer, thus weakening the rod. There are now several types of screw presses on the motor market for the purpose of straightening connecting rods and similar parts expeditiously and without damage or marking. The ordinary screw press, such as that used for arbors and bushes, can, of course, be used for this purpose, the connecting rod being held on suitable blocks one at either end, pressure being applied at the centre by means of a block of wood, or lead, through the agency of the press screw.

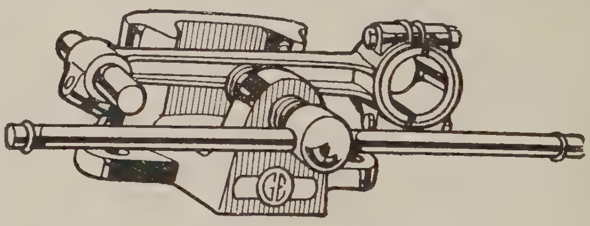

Fig. 351.—Another Connecting-rod Straightener.

Fig. 350 illustrates the method adopted by a well-known motor manufacturer for checking connecting rods for bend and twist. For the bend test a mandrel B is placed in the small-end bearing, and another A in the big-end one; this mandrel rests in V-blocks F. A scribing block carries a dial gauge C, which if there is no bending of the rod should give the same reading all along B. The rod is turned to the horizontal position, shown dotted at G, where it rests on a block D on the faceplate E. If there is no side twist the dial-gauge reading will be the same all along B, as indicated by the dotted diagrams.

Fig. 351 shows a form of straightener of the two-point and central-screw-press type. Here the rod is inserted so that the place to be bent back (or straightened) lies between the two fulcra or supports, and pressure is applied by means of a screw operated by a long handle. It is advisable, in this case, to place a piece of copper, lead, or hard wood between the screw end and the rod, to prevent local marking or damage.

It is not always possible to use the type of straightener described in order to take out a twist, but it is better to use a mandrel in the big end, and to anchor this securely in a vice, applying side pressure or torque with a suitable spanner so as to rectify the twisting distortion.

The Buma Roto-V-Test machine, illustrated in Fig. 352, which has been referred to previously, has been designed to test any connecting rod accurately for bending and also twisting effect by the usual methods. In addition, fitments are supplied which enable the rod to be straightened on the machine itself.

If, by the test applied, the rod is found to be bent, then it is held on the machine by the big-end mandrel and small-end fixtures, and a screw-operated fitment is placed on the rod, as shown in Fig. 352, and pressure applied to the central press, the two outer fulcra being used to hold the rod as a beam with central loading.

If the rod has been found to be twisted, another fixture having a pair of rods is clamped to the webbed portion of the rod near the big and small ends. At the upper end of each rod there is a trunnion that can rotate in its forked end. A screw device consisting of a screwed mandrel with operating handle is arranged so as to engage the trunnions in such a way that by operating the screw the ends of the two rods can be screwed together, or apart, as required, in order to apply the corrective torque to take out the twist. The rod is afterwards checked for zero twist by the mandrel and V-block method whilst in place on the machine. It will be observed that the checking and correction of faults can be carried out expeditiously and accurately in this machine.

The Big-end Bearings

Hitherto the general practice has been to employ a split type of connecting-rod big end, with white-metal formed integral with the cylindrical faces of the rod and its cap as the bearing metal. This method has given excellent results, and in connection with the servicing of worn engines it is possible to take up bearing wear in a straightforward manner, as will be described later. Further, in the case of badly worn or scored big-end bearings it is possible to melt out the old white-metal and replace this with new metal by the casting process, followed by machining to size. The technique of the methods employed is not difficult to learn, and the processes are further simplified by special fitments and equipment for remetalling and boring out the new bearings. These apply to both big-end and main crankshaft bearings. The only serious criticism of the method or type of big-end bearing mentioned is that an appreciable amount of

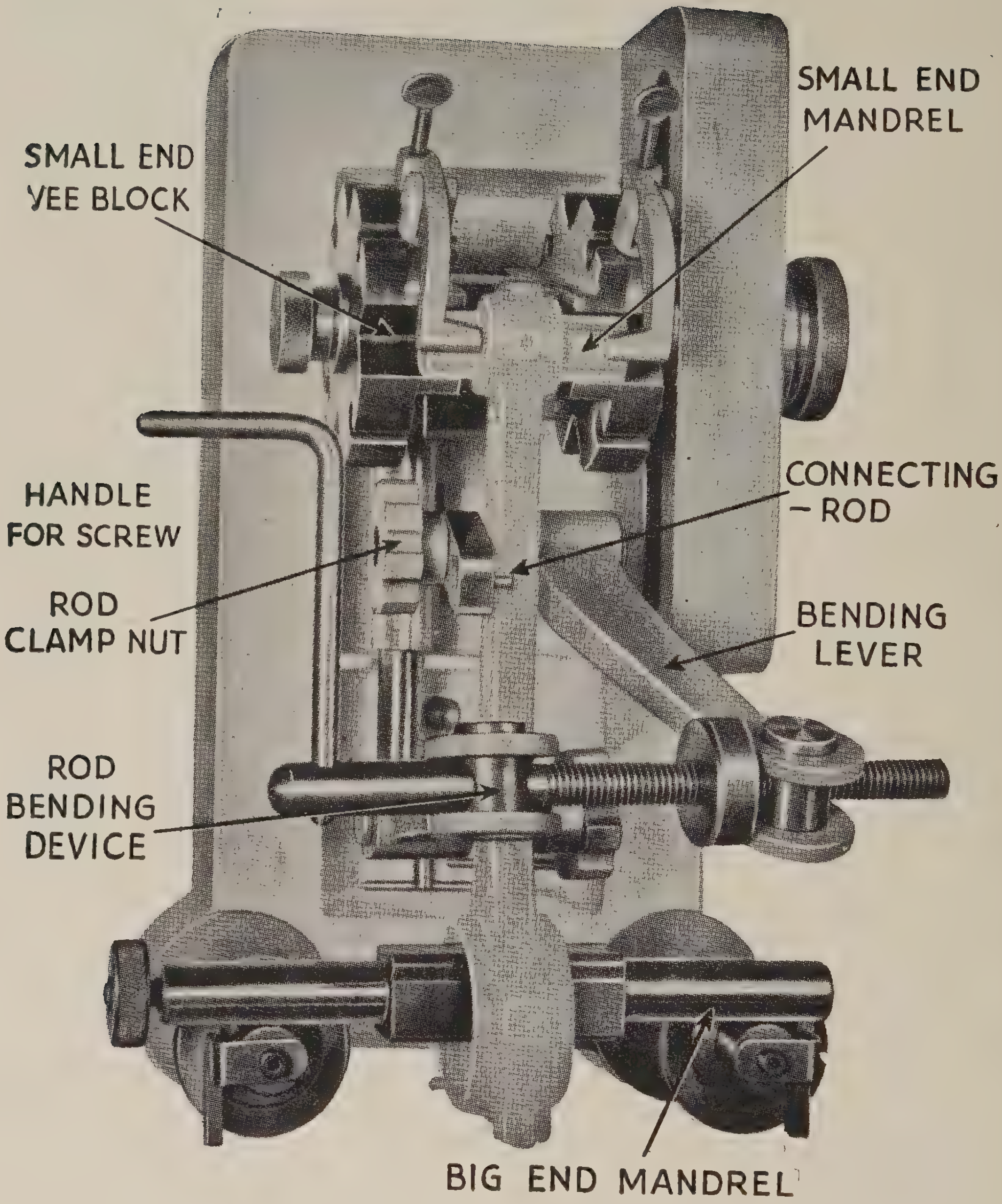

Fig. 352.—The Buma Connecting-rod Testing and Straightening Machine.

servicing time is involved, so that for routine overhaul purposes the operations are necessarily relatively expensive.

Shell-type Bearings

In the more recent designs of motor-vehicle engines this disadvantage has been overcome by the use of half-shells of bronze or steel lined with white-metal or other bearing alloy. The hard supporting shells require only a minimum thickness of white-metal, so that they can be made of relatively small thickness. The complete cylindrical bearing formed of the half shells is housed in the suitably machined big end or main bearing and located by means of the usual bearing caps. The half-shells, if merely held around the crank journals, would, of course, tend to rotate with the journals, and thus would wear on their outside surfaces. To prevent such rotation one (or both) half-shell is provided with a small projection (or projections), which fits into a recess (or recesses) machined in the cylindrical-bearing housing. *It is important when replacing the half-bearing to ensure that the projection and recess register correctly.*

There is another important point to remember in regard to shell bearings, namely, that *it is not possible to take up the effects of wear*, as in the earlier type, in which the white-metal is run into the bearing so as to become bonded with the steel housings. Therefore, when a shell-bearing wears the only remedy is to remove the two half-members, and if the journal is not measurably worn to fit a pair of new half-shell bearings.

A little reflection will indicate that if an attempt is made to close down the half-shells by filing on the flat faces of the shells—as is sometimes done with solid white-metal bearings—in order to reduce the internal diameter so that the half-shells will fit the journal, then the steel or bronze supporting shells will become loose in their housings, and the bearing will soon fail when under load. Under no circumstances, therefore, should the bearings be filed or scraped.

Examples of shell-type bearings are given in Fig. 129 on page 133; from these the principle and method of housing the bearings will be clear.

New shell bearings should be handled with care, as the steel is thin and the bearing metal has a very fine finish. When replacing the bearings see that the housings and their oil-holes are quite clean; further, make sure that the bearing caps are the correct way round.

Shell-bearing Sizes

Shell bearings are generally supplied in standard sizes to suit new crankshafts and undersizes for reground crankshafts. A typical range for a mass-production engine consists of standard and ·005, ·010, ·020, ·030, ·040, ·050, and ·060 in. undersize bearings. The usual bearing clearances on the diameters are ·0025–·0030 in. on end floats; big end, ·006–·012 in.; main bearings, ·004–·008 in. Usually the end float is controlled by the centre bearing.

Removing and Refitting Main Shell Bearings

Whilst the big-end half-shell bearings can readily be renewed, those of the main bearings, *when the crankshaft is in position*, are more difficult. The method employed in order not to injure the bearings is first to remove the main caps, and then to make use of a small fitment or gadget in the oil-hole of the journal such that when inserted and the crankshaft rotated by hand, the fitment projection pushes the half-shell around to the open cap position, where it can be removed by hand. Fig. 353 shows the method used on Vauxhall and Bedford engines, in which a split pin of $\frac{1}{8}$-in. diameter by $1\frac{1}{2}$-in. length is modified as shown. The altered split pin is then inserted into the journal oil-hole (Fig. 354), when the projecting end of the split pin can be used to rotate the half-shell for removal.

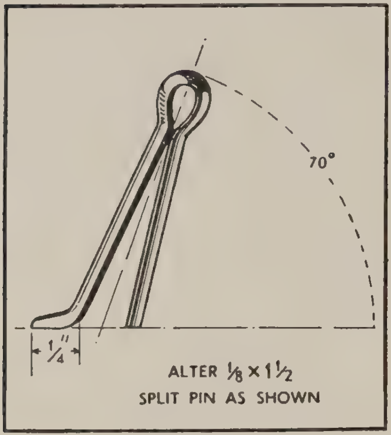

Fig. 353.

The method used for Chrysler shell bearings is to fit a T-shaped device into the oil-hole and use the end projection for rotating the half-shell. Alternatively, an odd half-shell bearing can be used to start the main half-shell bearing for removal purposes.

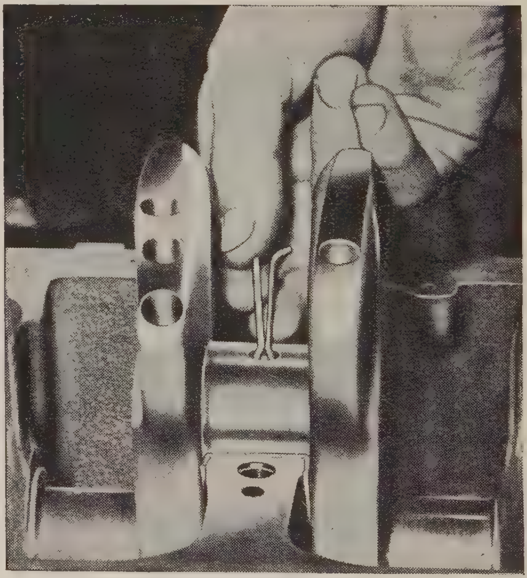

Fig. 354.—Inserting Altered Split Pin in Oil-hole to Remove Bearing Shell.

White-metalled Bearings

The solid white-metalled, as distinct from the shell-type, bearings previously referred to are used on many vehicle engines in present-day service, and for this reason it is proposed to consider their adjustment and servicing.

Fig. 355 shows the crankshaft, connecting rod, and main bearings of the post-war Morris commercial vehicle LC and PV model engines. It will be observed that these bearings are of the white-metalled type, with shims between the split faces for adjustment purposes. Incidentally, the piston (21) shown in this illustration is of the wire-wound pattern.

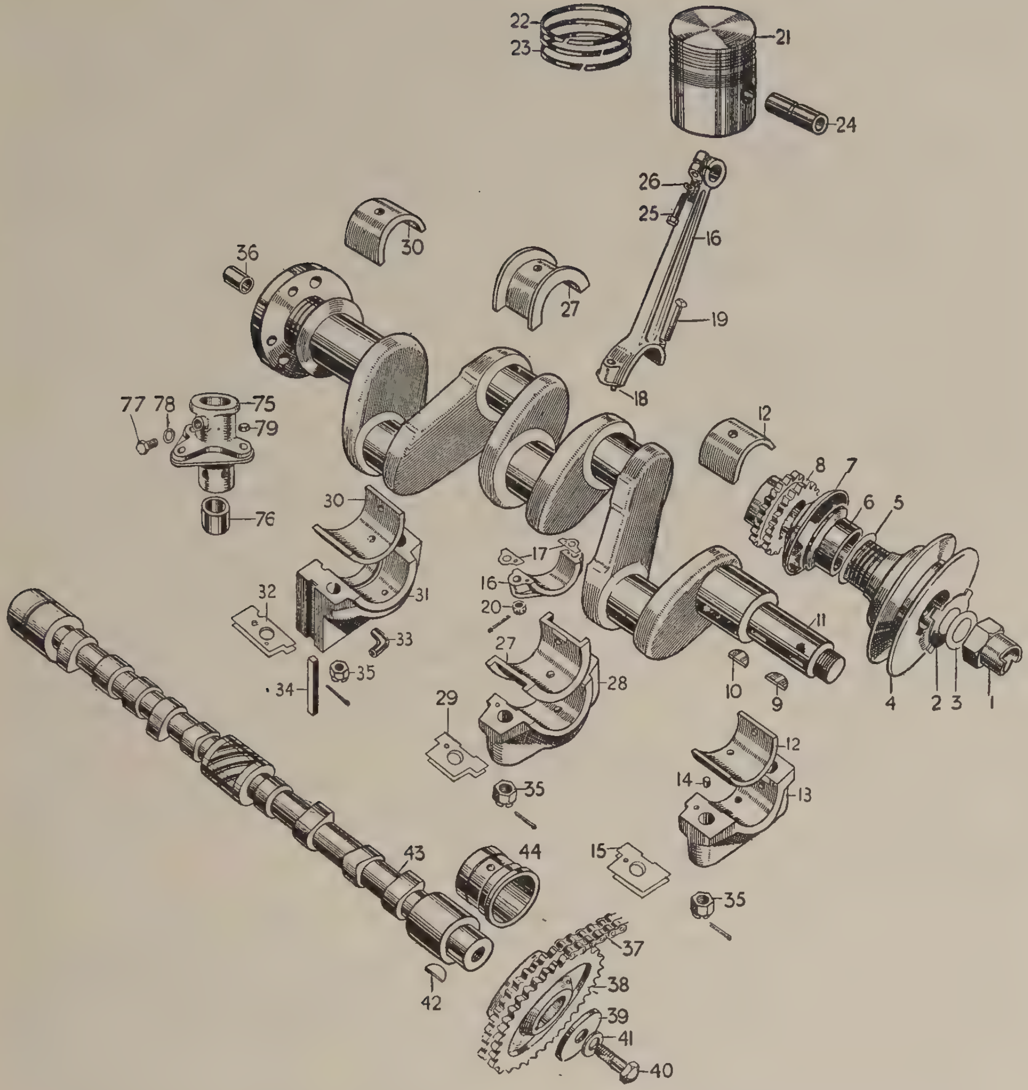

Fig. 355.—Piston, Connecting Rod, Crankshaft, and Bearings of Morris LC and PV Engines.

Key. 1—Starting Jaw. 2—Lock Washer. 3—Shims (·010 in. and ·015 in.). 4—Fan Pulley on Crankshaft. 5—Fan Pulley Shim. 6—Timing-case Sleeve. 7—Crankshaft Oil Thrower. 8—Crankshaft Chain Wheel. 9—Chain-wheel Key. 10—Fan Pulley Key. 11—Crankshaft. 12—Front Main Bearing. 13—Front Bearing Cap. 14—Dowel for Main Bearings. 15—Shims for Front Bearing (·002 in. and ·003 in.). 16—Connecting-rod Assembly. 17—Shims for Connecting Rod. 18—Dowel for Connecting-rod Shims. 19—Connecting-rod Bolt. 20—Nut for 19. 21—Piston. 22—Compression Ring. 23—Scraper Ring. 24—Gudgeon Pin. 25—Small-end Pinchbolt. 26—Spring Washer. 27—Centre Main Bearing. 28—Centre Bearing Cap. 29—Shims for Centre Bearing (·002 in. and ·003 in.). 30—Rear Main Bearing. 31—Cap with Drain-pipe for Rear Main Bearing. 32—Shims for Rear Bearing (·002 in. and ·003 in.). 33—Pipe for Rear Bearing Drain. 34—Seal for Rear Bearing. 35—Castle Nut for Crankshaft Bearing Cap. 36—Bearing in Crankshaft for Stem Wheel. 37—Timing Chain. 38—Chain Wheel for Camshaft. 39—Chain-wheel Washer. 40—Set Bolt. 41—Washer. 42—Key, Chain Wheel to Camshaft. 43—Camshaft. 44—Camshaft Front Bearing.

Adjusting Big-end Bearings

We shall now consider the matter of adjusting worn big-end bearings, afterwards describing re-white-metalling methods. When an engine is dismantled for general overhaul and replacement purposes, the fit of the big-end bearings should be checked, by first cleaning thoroughly—as the oil-film masks the slackness—both the bearings and the crank-pins, and after reassembling these items, testing the amount of play in a direction along the length of the rod, and with the crank at about 45° to 90° from the top dead centre in the direction of its rotation; this corresponds to the line of maximum connecting-rod thrust and wear. To be quite certain of this, try the bearing with the rod at various angles.

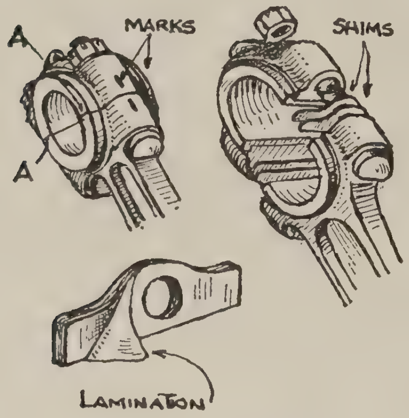

Fig. 356.—The Connecting-rod Big-end Bearing and its Components.

If the crank-pin is perfectly round the bearing will fit equally well in all positions; if, as often happens, *the pin has worn slightly oval*, the bearing will be free in the position above indicated and tighter in other positions. The crank-pin *should certainly be trued up*, by one or other of the methods described in the next section before attempting to adjust the big-end bearings.

The amount of rock in a sideways direction which can be given to the connecting rod when in position on the crank-pin is also an indication of the amount of wear.

The correct method of ascertaining the amount of wear is, of course, by an accurate micrometer measurement of the crank-pin and bearing diameter. The allowable clearance between the two when newly assembled and bedded in varies between ·001 in. and ·0015 in. in the case of a $2\frac{1}{2}$-in.-diameter pin. If the measured clearance exceeds about ·005 in. to ·007 in., it is a sign that the bearing should be taken up.

If the wear found is not serious, it can usually be taken up satisfactorily by removing a shim (·002 in. to ·004 in.). The operation of taking up a worn bearing is as follows: Take off the cap by removing the nuts from the connecting-rod bolts, and take out the thinnest shim or packing liner from between the two halves of the bearing (Fig. 356). Replace the cap on the rod in place on the crank-pin. Test for " feel " or play. If the rod will just swing down from the horizontal position under its own weight, the fit is about correct.

It is advisable to use a marking on the crank-pin, such as Prussian blue, or red lead and oil, and after removing a shim and trying the bearings on the crank-pin to scrape away carefully the high parts until the bearing touches evenly all over, when the connecting-rod bolts are tightened up securely. It is a job which requires both skill and experience to obtain, by scraping, a perfectly well-bedded bearing, and at the same time the correct amount of clearance.

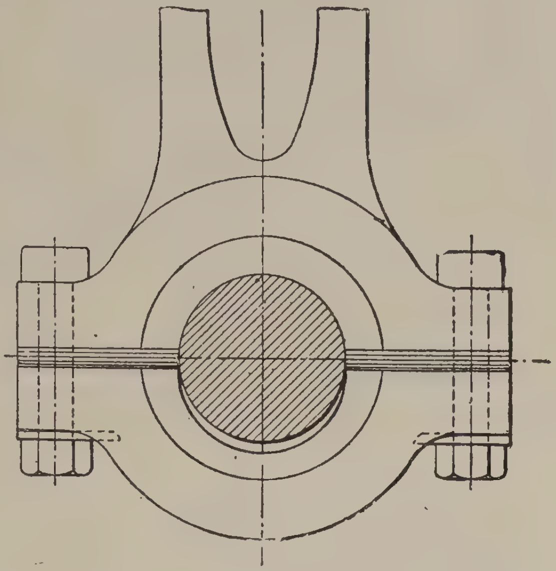

Fig. 357.—A Badly Worn Bearing (wear shown exaggerated).

When a bearing is taken up by the removal of a shim, it will only bed on two places, namely on the top and bottom, A and B, as shown in Fig. 358. There will be a clearance at C. The surplus metal at A and B should be removed by scraping until the whole bearing fits the pin.

The finished scraped-in bearing, when the bolts are fully tightened, should be a shade on the stiff, rather than on the easy, fitting side, to allow for the subsequent flattening out of the high spots under the hammering action of the piston when the engine is working. As we have stated, the rod should just be able to swing downwards from the horizontal position, if given a start.

An excellent method—and one we have frequently employed—for obtaining a good well-bedded bearing straight away is to fit the bearings a little on the tight side, so that it requires a few pounds' pull on the small-end to rotate the rod. Then give the cap of the bearing a number of sharp taps with a hammer, and afterwards the parts of the connecting rod at the back of the other bearing cap. It will be found that not only is the bearing eased to the correct degree due to the high spots being hammered down,

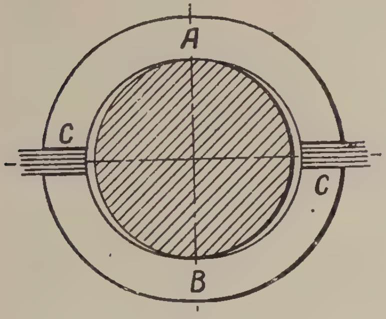

Fig. 358.—A Worn Bearing after taking out Shims.

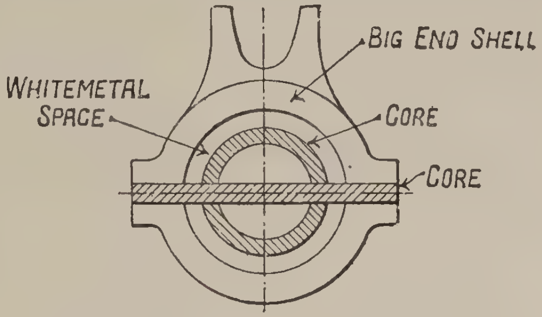

Fig. 359.—Illustrating the Method of Re-metalling a Big-end Bearing.

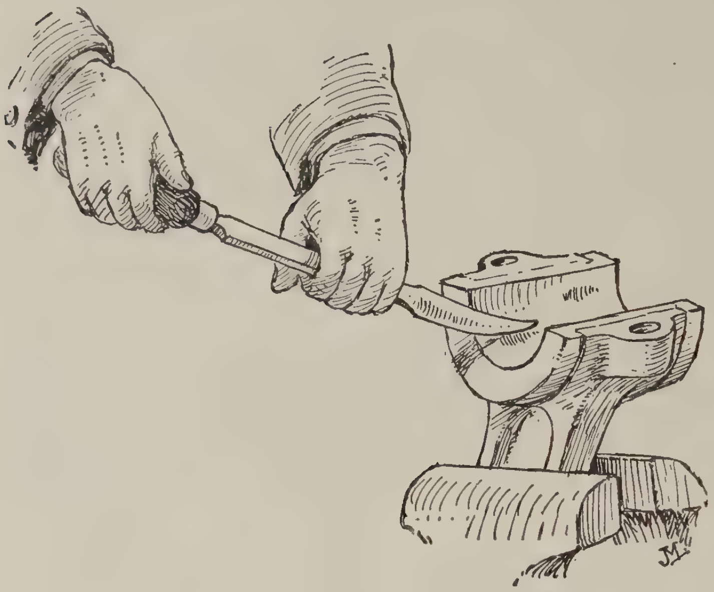

Fig. 360.—Method of scraping in a Big-end Bearing.

but that no further bedding will be required. After tapping the bearing, the rod should be rocked each time until it is found to be free to the proper extent. This method should not, however, be abused, by employing it to pass badly fitted bearings.

If the crank-pins are not worn, or are all of the same diameter after truing, it is sometimes better to make a dummy crank-pin, by turning to exact size a piece of steel in the lathe and polishing it. The bearings can then be lapped, or otherwise fitted on this shaft, in turn.

Bearing Clearance Measurement

A simple and convenient device for measuring the bearing clearance of the connecting-rod big end and small end respectively is shown in Fig. 361. It consists of two shaped steel bars rigidly coupled together so as to form a holder for a dial gauge. The holder can be clamped to the connecting rod at any desired place, when in position on the engine, working below from the crankcase. Clamping is effected by means of a roller chain. One end of the latter is fixed to a screwed rod having a butterfly nut, and the other end passes through a collar drilled to take a pin in any link of the chain, so that the holder can be used on a range of different sizes of connecting rod. When fitted by tightening up the butterfly nut, the holder is arranged at right angles to the connecting rod.

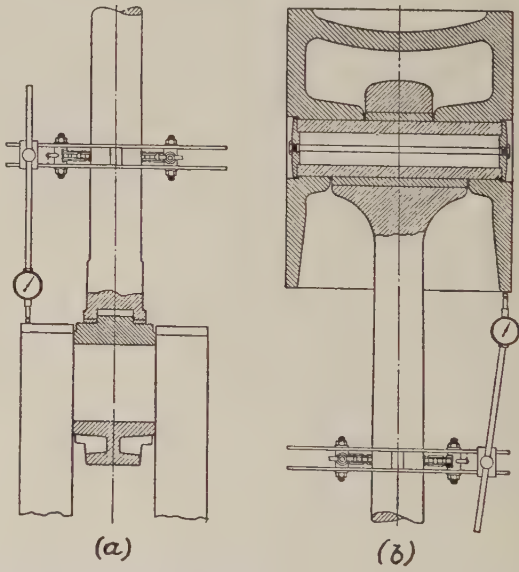

Fig. 361.—Bearing Clearance Measurement Device (H. D. Adam).

To measure the big-end clearance ((*a*) Fig. 361), the dial-gauge readings are taken when the connecting rod is pulled or pushed to its top and bottom positions, with the crank on top or bottom dead centre. For small-end clearances ((*b*) Fig. 361), the connecting rod is pulled or pushed to give the two extreme (top and bottom) readings. The difference between these readings, in each case, denotes the bearing clearance. A lever should be used under the big-end cap for the purpose described.

Badly Worn Bearings

If on examination the surfaces of the white-metal bearings show *distinct groovings* or *markings*, due to *grit* or to *partial seizure*, or if, on the other hand, the white-metal *is worn thin* and is *broken away in places*, the bearings should be re-metalled; the worn surface should be quite smooth and sound, and the bearing metal of sufficient thickness.

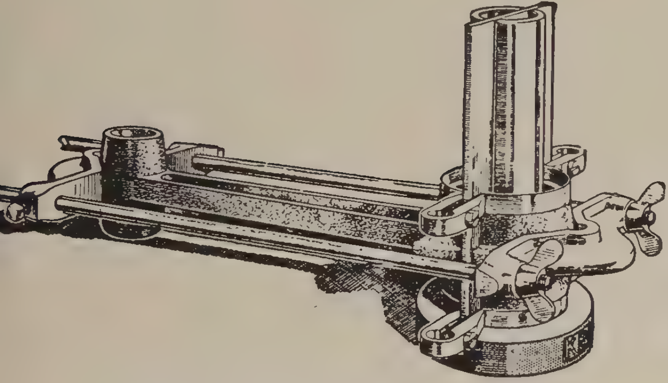

Fig. 362.—The K.B. Connecting-rod Bearing Mould.

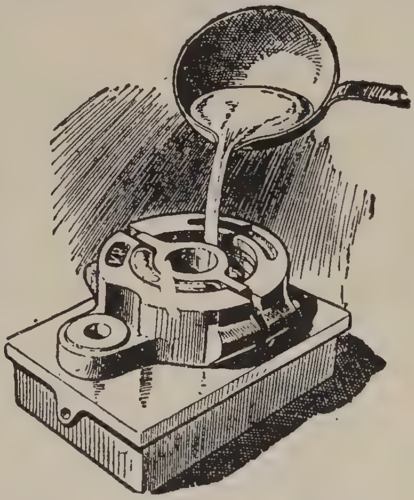

Fig. 363.—The K.B. Main Bearing Mould.

It is not a difficult matter to re-metal a bearing, as there is a number of alternative patterns of bearing mould on the market, especially designed for bearing re-lining purposes. We shall describe two or three typical moulds for this purpose, afterwards mentioning the most suitable bearing metals used and actual methods of re-metalling.

Fig. 362 illustrates the K.B. big-end bearing mould, made by the Mansions Motor Co. It consists of a light hollow cast-iron core standing upon a light base. This core represents the part of the mould corresponding to the inner surface of the bearing (Fig. 363). It is made hollow, so as to give rapid cooling after the metal is poured. The steel-plate portion of the core is to divide the bearing into its two halves. An accurately machined clamp enables either a pair of brasses or a connecting rod to be securely fixed to the plate, using either long or short rods supplied for the purpose.

It is necessary to provide thin metal rings, one at each end, held in place by means of the spring clips shown (Fig. 362) to form the outside edges of the bearing.

The K.B. main bearing mould (Fig. 363) is of somewhat simpler design, but employs the same basic principles.

The Forwell Re-metalling Jig

An improved design of white-metalling jig for bearings which enables sound bearings to be obtained every time, free from inclusions, blowholes or other defects, is the Forwell one,[1] the principle of which is illustrated in Fig. 364.

In this device the mandrel is hollow and the metal is poured in at A, flows through the hole B, and fills the space C between the mandrel and the bearing shell or connecting rod. The mandrel (core) is maintained at approximately the same temperature as the metal being poured in; thus the metal which cools at the point of contact with the bearing (causing a consequent shrinkage of this metal in the recess) is replaced by a flow of liquid metal from A. "Puddling" or "venting" of the white-metal with a wire is dispensed with.

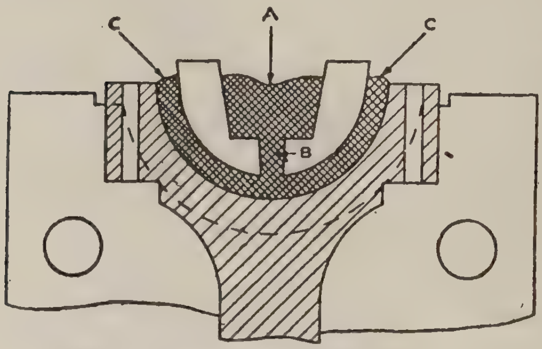

Fig. 364.—The Forwell Re-metalling Jig.

The manufacturers claim that 15 connecting rods can be tinned and re-babbitted within an hour, with absolute ease.

The Forwell jig is mounted on an all-steel welded stand, fitted with a bellows and blowpipe, ready for connecting to the gas supply. The stand itself is fitted with useful shelves to accommodate trays for formers and cores.

Two melting-pots, heated by separate gas burners, are provided, one of which can be used for running out the old white-metal or for tinning; and the other for holding the new metal. Provision is made for pre-heating the mandrels or cores. Ladle and tongs are included, also a large tray, placed under the jig, to avoid the wasting of metal through spills, etc.

Connecting-rod Boring Tools

The bearings thus cast can either be scraped or reamed to size. In the latter case it is interesting to note that the same firm manufactures a neat form of connecting-rod reamer and jig for finishing re-metalled big-end bearings to exact size.

The jig, which is shown in Fig. 365, secures the rod in the correct position for reaming. A suitable pin holds the small-end of the rod, whilst two hand-operated nuts secure the big-end in the correct position, so that the fluted reamer is automatically located relatively to the rod; the correct distance between the centres of the big- and small-ends of the connecting rod is thus assured. Another advantage of this jig is that the big-end bearing is finished dead true with the small-end ones, so that there is strict parallelism of the two axes.

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[1] Ford Welding Co., Ltd., Cardiff.

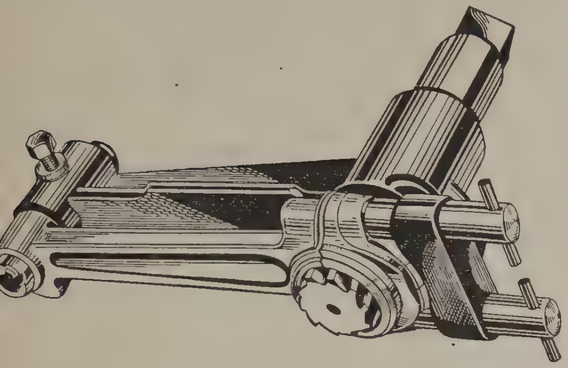

Fig. 365.—Connecting-rod Reamer and Alignment Jig.

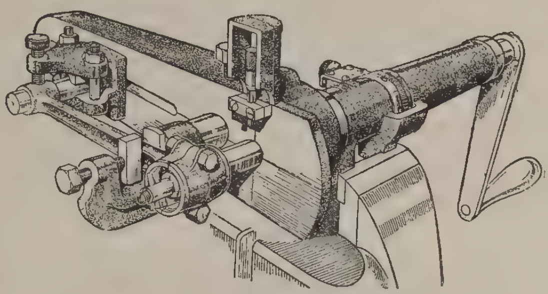

Fig. 366.—The K.B. Connecting-rod Boring Tool.

The K.B. connecting-rod boring tool shown in Fig. 366 consists of a special bracket, forming a jig for holding the rod, and containing a long bearing for the boring-cutter shaft to ensure accuracy and steadiness. The tool is operated by means of the handle shown, and a variable feed can be put into action when required. A special micrometer is provided for setting the radius of the boring cutter, so that the bearing can be bored to

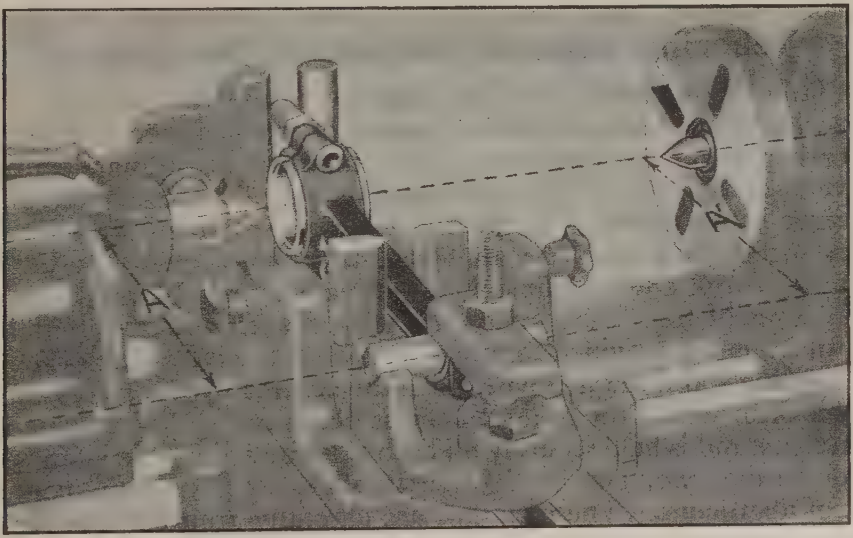

Fig. 367.—Jig for Boring Big-ends in the Lathe.

an accuracy of within less than ·001 in. of dead size. The tool is so designed that it is adjustable for any length of connecting rod from 7 to 15 in. between the centres; the gudgeon pin and big-end bearing axes are accurately aligned, and the correct distance between the side or end faces of the big-end bearing and the centre line of the connecting rod can readily be set. A scribing block is supplied with the tool to enable the big-end faces to be set central with the connecting rod, or offset to the desired amount. With this device the whole of the machining is done at one operation.

The same tool can be used in conjunction with a special K.B. bearing jig for the purpose of boring main bearings.

A combined big-end bearing reaming and burnishing tool, known as the B.T.S. tool,[1] is illustrated in Fig. 368. It has five burnishing blades and one cutter blade; the burnishers act as steadies during the cutting operation. They are mounted in slots in the main spindle, a knurled nut being provided at the top of the spindle to expand or contract the cutting and burnishing blades simultaneously. A sleeve is fitted on the spindle at the lower end of the blades, and with the aid of a spring keeps the blades tight up against the top adjusting nut. With a pre-set stop it is possible to ream and burnish big-end bearings all to the same size. The tool in question has a range of $1\frac{1}{4}$–2 in.

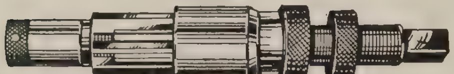

Fig. 368.—The B.T.S. Big-end Reamer and Burnisher.

Reboring Big-end Bearings in the Lathe

The lathe is probably the best machine to use for reboring big-end bearings which have been re-metalled, unless of course a special big-end and main-bearing borer is available. If a number of similar connecting rods have to be rebored it is better to employ a jig for holding and aligning the bearings in the lathe. Fig. 369 illustrates the method of mounting the rod in such a jig; the latter is a universal attachment, made by the South Bend Lathe Works, having adjustable stops which permit mounting various sizes and types of connecting rods. A finished surface along the left edge of the attachment is provided for aligning it with the face plate of the lathe. The connecting rod is aligned with the lathe centres by means of an adjustable V-block in which the gudgeon pin is clamped. The opposite end of the connecting rod is held securely on both sides by adjustable clamps which are made so that they can be tightened without springing the connecting rod out of alignment. These clamps are carefully adjusted and tightened after the gudgeon pin is clamped on the V-block. The bearing is then centred by means of a machined rod placed between the lathe centres, using callipers to check the distances between the rod and the bearing until, by adjustment, these are equal. Another method is to place a *conical mandrel* between the centres and to adjust the position of the rod until the

[1] Thompson, Craven, Ltd., Malton, Yorkshire.

mandrel touches equally all parts of the bearing. The slide rest should then be locked in position.

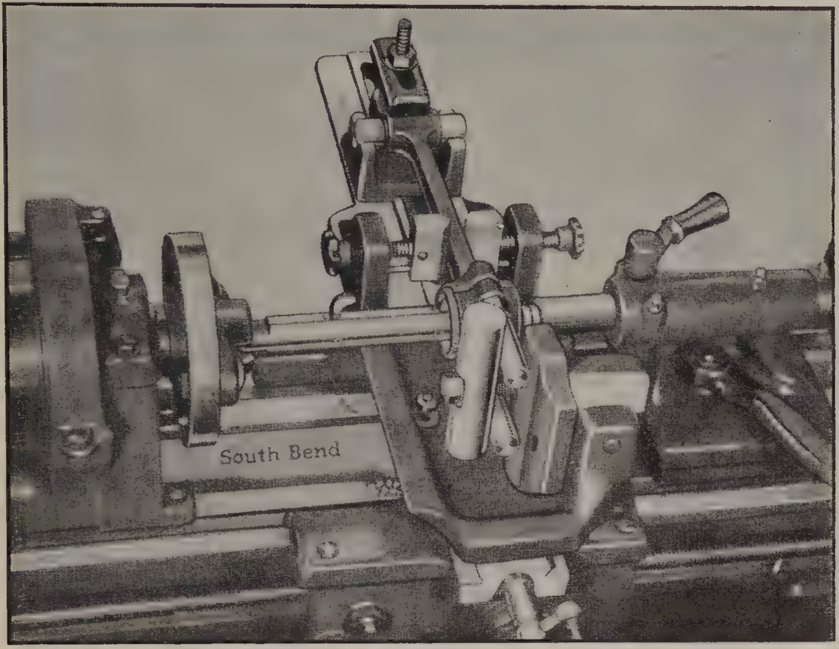

Fig. 369.—Showing Boring Bar in Position.

The actual boring is done with a boring bar (Fig. 370) having an adjustable-radius cutter bit—preferably of the tungsten-carbide type. One end of the cutter bar is held by the self-centring chuck, or a carrier and face-plate pin may be used to drive the boring bar, which is then mounted

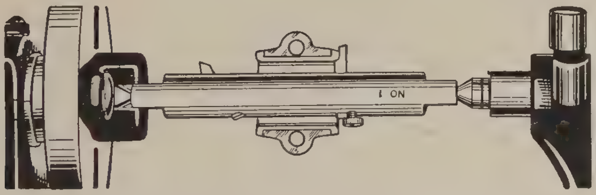

Fig. 370.—Boring Bar, showing Boring and Facing Cutters.

between the lathe centres. A special direct-reading micrometer (Fig. 371) is used to set the cutter bit to the correct radius for boring to the proper diameter. The latter is a few thousandths less than the crank-pin journal, to allow for scraping in, or if a proper finishing tool is used it can be arranged to machine the bearing to the final diameter. It is, however, advisable to use two boring bars, one for roughing and the other for finishing.

The cutting edge of the finishing bit, if of tool steel, should *be honed to a keen edge* with a small oil-stone in order to obtain a finely polished surface on the bearing. *The best tools* to use for finishing are the diamond-pointed and the tungsten-carbide-tipped bits such as "Wimet" or "Ardoloy" ones. The end faces of the bearing are machined with special side-cutting tool bits held in the boring bar in a similar manner to that of the boring bit. These end bits are used for facing, radiusing, and trimming the outside of the bearing (Fig. 371). It is usual to mount both the bore-finishing and the end-facing bits at a certain distance apart in the *same boring bar*. The movement of the lathe saddle, which carries the connecting rod and its jig is employed to apply the cut or feed as the case may be.

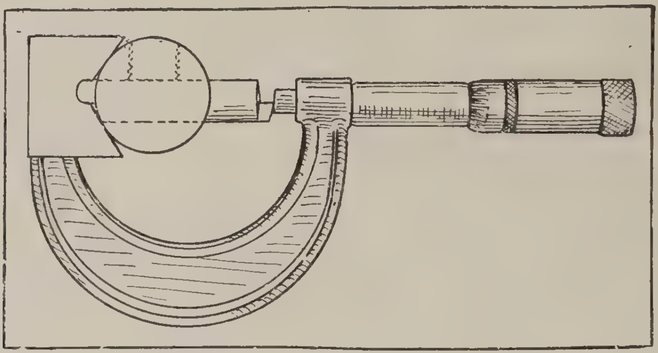

Fig. 371.—Setting the Radius of Cutter Bit with Micrometer.

The liners and shims should, of course, be in position when a connecting rod is bored to final dimensions, the two parts of the bearing being clamped tightly with the connecting-rod bolts and nuts.

A cutting speed of from 500 to 800 ft. per minute should be used with ordinary high-speed tool steel; much higher speeds are possible for diamond and tungsten-carbide tools.

The T.W. Hand-operated Connecting-rod Borer

This well-designed machine[1] enables a wide range of different designs and sizes of connecting-rod big-end bearings to be bored accurately, faced on the ends of the bearings, and radiused. The machine illustrated in Fig. 372 will accommodate connecting rods of $5\frac{1}{2}$-in. to $12\frac{1}{2}$-in. centres. To the left of the frame of the machine there is a U-shaped casting which can slide end-wise on four locating and guide spindles; it can be clamped in any endwise position on these guides. The U-shaped casting is provided with three pointed-end locating and fixing screws, having knurled ends for hand adjustment. One of these screws has a lock-nut, so that having located one connecting rod, with the aid also of an adjustable V-block to take the

[1] Cuthbert Machine Tools Ltd., Guildford, Surrey.

gudgeon pin in the small-end bearing below, another rod of the same pattern (in the case of multi-cylinder engines) can readily be substituted, without affecting the location, merely by unscrewing the other two pointed screws, removing the first rod and inserting the second; afterwards the pointed screws are screwed up against the connecting rod. The boring bar has two substantial bearings and there is a simple adjustment by screw-driver for the convenient movement of the boring bar. The machine is provided with a micrometer for setting the tool-bit radius and an internal and external scriber (mounted in a similar holder to that used for the micrometer).

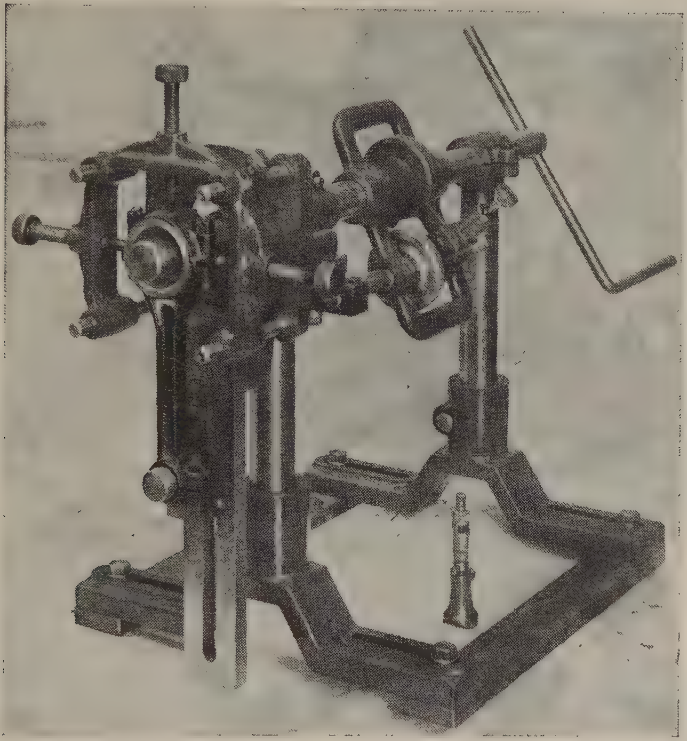

Fig. 372.—The T.W. Hand-operated Connecting-rod Boring Machine.

Automatic pawl, ratchet, nut-and-screw feed is arranged for the boring bar.

Power-driven Boring Machine

A power-driven machine (Fig. 373) is also made for the same purpose. This has a cone-pulley drive giving speeds of about 600, 900 and 1,400 r.p.m. for the boring bar. The latter speed is satisfactory for use with diamond boring tools on all diameters and with the smooth automatic feed of ·002 in. per revolution of the bar an excellent surface finish is obtainable. Special means are provided for the rapid setting up of the connecting rod, by means of a half-cone device; and once set for one rod, all rods of similar pattern can be set up without breaking the big-end bearing joint.

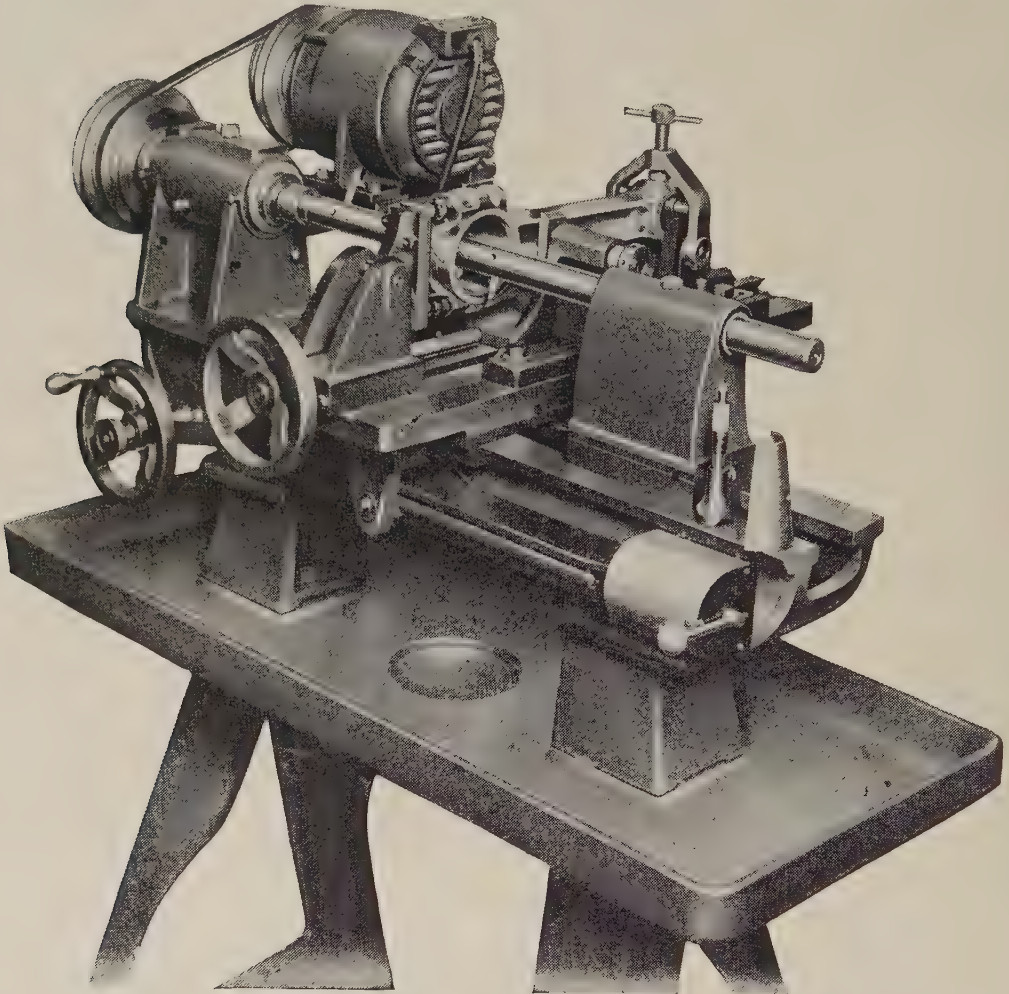

Fig. 373.—Power-operated Connecting-rod Boring Machine.

Tests for Connecting-rod Bearing Fit

After a big-end bearing has been re-metalled, or taken up, rebored, and scraped, it should have a certain small clearance on the crank-pin. To allow for a slight bedding down of the higher spots left by scraping, the bearing, when its cap bolts are properly tightened, should be a little on the tight-fitting side; the amount of this should, however, be very slight. A very good indication of the proper degree of tightness to allow is to place the rod about 15° to 20° out of the vertical on its crank-pin, when it should fall, by virtue of its own weight, to the corresponding lower position (Fig. 374); the bearing should be no tighter than the condition indicated.

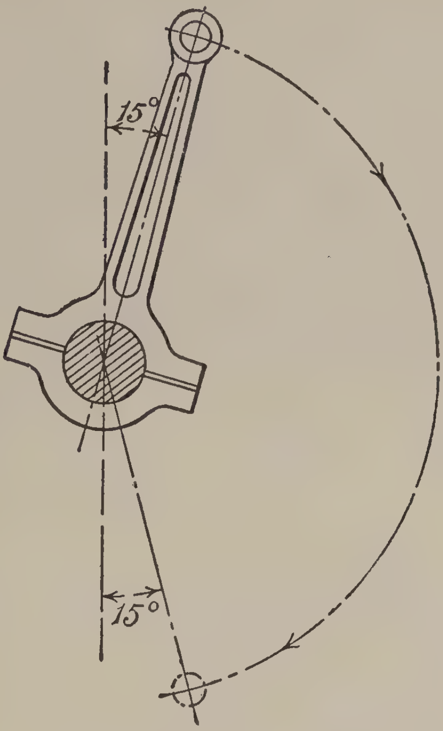

Fig. 374.—Test for Connecting-rod Bearing Fit.

Adjustments to Main Bearings

Although it is not a difficult matter to the skilled mechanic to adjust or renew a single bearing, such as a big-end bearing, it requires a certain amount of skill and experience to fit correctly and line up two, three, or a larger number of bearings in the case of the crankshaft. Not only must each bearing be a satisfactory fit on its journal, but all the bearings must be *in line* with each other —that is to say, must have the same common axis. Further, in addition to being in line, their common axis must be at right angles to the cylinder axis.

It is not uncommon when testing crankshaft bearings to find a slight tilt —more especially in the case of a two-bearing shaft—relatively to the correct position. Such a tilting produces a side-pressure on the pistons and the connecting-rod bearing, and generally results in a loss of power due to excessive friction.

Although it is still the practice in many garages to scrape the bearings in by hand, the use of a boring jig or fixture to bore all the main bearings in one operation is strongly recommended, since, if the original lining up is correct, the final result will give true alignment of all bearings. Before proceeding to describe a typical main-bearing boring fixture, it is proposed to make a few notes in connection with the hand adjustment, alignment, and checking of main bearings.

It is essential to commence work on the crankcase bearings with a perfectly true crankshaft; the journals should be truly cylindrical and the axes in one line.

For operations on the main bearings, it is necessary to work on a convenient bench, so that accurate alignment with the crankcase in the chassis frame is not permissible. A good face plate is another practically essential item, although with a little ingenuity it may be dispensed with on occasions.

We will assume that the crankcase is mounted on the bench, the bearings have been re-metalled to scraping limits, and the crankshaft reground to equal journal diameters.

The crankcase should be supported as shown in Fig. 375 on the face plate. A scribing block with an adjustable scriber of the bent pattern should be used, roughly to check the levels of each of the main bearings in turn; it may be necessary to use an extra-long scriber, but if this is the case there should be no undue "spring" in it. In this way a good idea of the relative levels of the bearings is obtained; and any bearing which is unduly low should be properly packed, whilst a high one must be lowered, either by filing the shell or by scraping the bearing metal. A dial gauge should then be used for the final fitting and alignment operations.

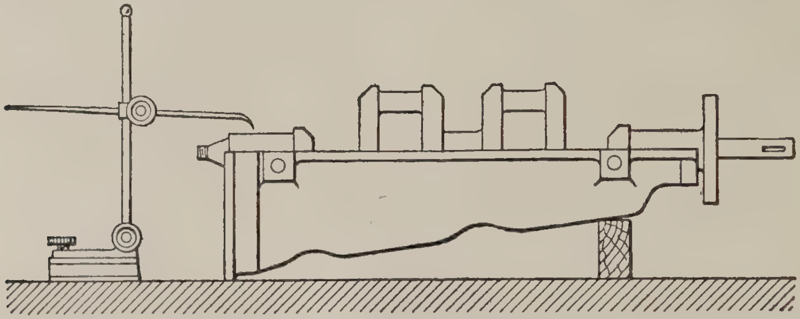

Fig. 375.—Illustrating Method of checking Main Bearings during Truing Operations.

Fig. 376 shows the Mercer dial gauge which is used instead of a scribing block in the modern motor works.

When all of the bearings are in line, the crankshaft can be used as a mandrel for scraping the bearings too. If the journals be rubbed lightly with some marking, such as Prussian blue or lamp-black and oil, the bearings can be gradually eased by judicious scraping until the journals touch evenly on them. The alignment of the bearings should then be checked with the scribing block on the face plate, leaving the crankshaft in place, and using the scriber or, better still, a feeler gauge of the Starrett dial type.

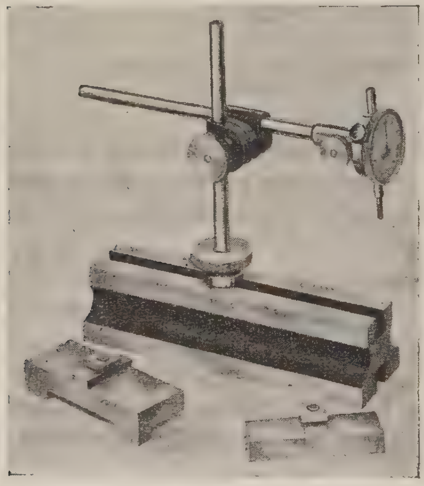

Fig. 376.—Mercer Dial Gauge as used for checking Crankshaft Alignment.

If *no face plate is available* the machined face of the crankcase can be worked off by placing a straight-edge across this surface, and measuring the distance between the lower edge of the former and the bearing or crankshaft journal.

In any case, the crankshaft axis should be kept parallel with the machined surface of the crankcase during bearing-scraping operations.

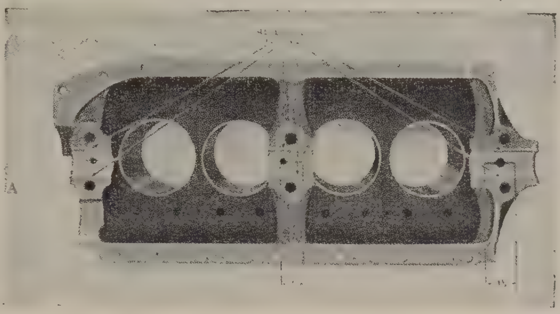

Fig. 377.—The Main Bearings (Crankcase shown upside down); Oil Grooves and Chamfers are also indicated.

The flanges of the bearings and the radii of these flanges should be eased so that there is no tendency for the crankshaft to jamb between them; the end clearance should not be appreciable, but if a thrust race is fitted to the crankshaft the end clearance can be appreciably more than usual.

When the main bearings have been scraped in properly, the marking on the crankshaft will show a number of areas of contact uniformly scattered. The final process of finishing a bearing in this condition is to clean it thoroughly (and also the shaft), and to apply the marking *to the bearing surface* itself, afterwards rotating the crankshaft for some time. On removing the latter and examining the bearing surfaces, a number of bright spots will be observed on which there is no marking; these are the high spots. A very light scraping or rubbing down should then be given to break down these high spots into " bearing patches."

The next operation is to fit the bearing caps or keeps. Here the objects to aim at are a uniform bearing area and a running fit when the keep is bolted down as tightly as it will go. The operation of scraping in a keep is similar to that of any other bearing, and in this case it necessitates, after the preliminary roughing and lining-up, a frequent bolting up and unbolting of the bearing cap or keep. It is a more difficult operation than that of the first half-bearings, since, in addition to the keep having to bed uniformly, it also has to provide the correct running clearance.

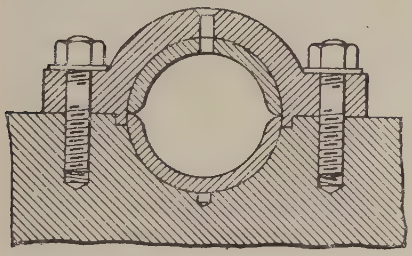

Fig. 378.—Fitting the Bearing Caps.

Running in of Main Bearings

It is now considered good practice to fit the caps so that the crankshaft rotates a little on the tight side when the former are bolted up securely, and to run the crankshaft in, using the ordinary workshop shafting for the purpose. The flywheel can be used as the belt pulley, or a split-wood pulley fitted on the crankshaft for rotating the latter. The engine stands shown in Vol. II of this work are suitable for this purpose. The bearing should be run in on an engine stand at a speed of 200 to 400 r.p.m., plenty of lubricant being provided—in fact, the bearing should be kept flooded. After several hours' running in, the crankshaft and bearings should be cleaned thoroughly, and assembled again, dry, in order to test for excessive clearance, due to "bedding down"; in this eventuality, the bearing halves must be let together a little and re-scraped. It is unlikely, however, that this state of affairs will occur, more particularly if the bearings are finished a little on the tight side before they are "run in."

A set of bearings which have been run in properly are in a satisfactory condition for running the engine at practically any of its speeds without further bedding in; it is always a wise precaution, however, to run a reconditioned engine slowly for the first few hours of its new life.

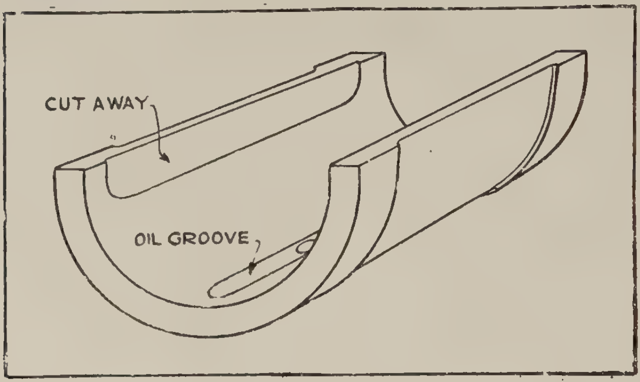

Fig. 379.—Grooves for Sediment Collection.

Notes on Main-bearings Servicing

The clearances between the main journals and their bearings when correctly machined or adjusted should lie between ·0015–·003 in., and the end clearance or float ·004–·006 in., according to the type of engine.

In the earlier vehicle engines, which ran at lower speeds than post-war ones, it was the rule to machine away grooves—known as *sediment grooves*—as shown in Fig. 379, in order to trap any fine particles in the oil and thereby avoid some of the wear that would otherwise occur. In the more recent engines, which run at higher speeds, these grooves are absent in the bearings, the reasons being that (1) this area is required on account of the bearing pressures due to the centrifugal loadings, and (2) the oil is filtered more thoroughly, so that very few if any fine particles of solid matter can reach the bearings. The modern shell bearings are therefore of the unbroken cylindrical pattern with no sediment grooves. It might here be added that another reason advanced for the introduction of these grooves was that they formed oil reservoirs from which the oil was drawn round into the more heavily loaded areas; efficient oil grooves, however, perform this function more satisfactorily.

In the case of four- and six-cylinder engines having a single centre or two centre main bearings, it is often found that owing to crankshaft "whip" or deflection at certain (synchronous) engine speeds the inside or centre bearing or bearings *become worn more than the two outside ones.* When taking up the wear of the bearings it will be found that after the outside bearings have first been bedded down correctly there may still remain an appreciable amount of clearance in the centre bearing or bearings which, if left, will *cause a knock* at certain engine speeds. It is necessary, in this case, to bed down the outside bearings further, until the centre-bearing clearance can be reduced, by removal of shims and scraping, to the correct clearance value. It is thus important not to take up play in the centre bearings first without making the necessary adjustments to the outside bearings as well, otherwise crankshaft distortion or binding may occur.

Crankshaft End Float

The end float or side clearance of a crankshaft is specified by the engine manufacturers, and this clearance should be checked with a feeler gauge.

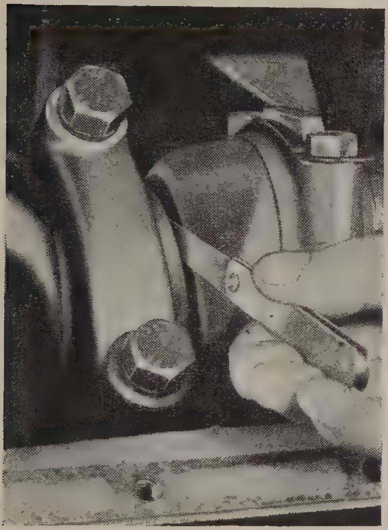

Fig. 380.—Measuring the Crankshaft End Float on Vanguard Engine.

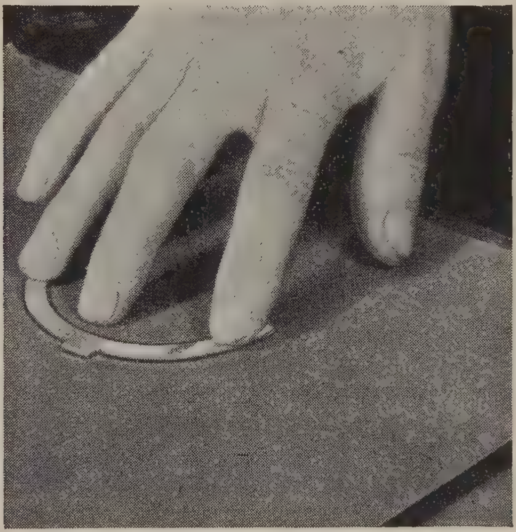

Fig. 381.—Reducing Thickness of Thrust Washer for Crankshaft of Vanguard Engine.

Thus in a typical case, namely the Standard Vanguard engine, the main-bearing clearance when new is ·001 in. to ·002 in., and when this clearance exceeds ·006 in. the crankshaft will probably need regrinding and new undersize main bearings.

In regard to end float, this is specified as ·004 in. to ·006 in., and is measured as shown in Fig. 380. It is controlled by means of thrust washers. If after fitting new washers the end float is not enough, the washer should be rubbed down on a piece of emery cloth, as shown in Fig. 381. Oversize thrust washers may be obtained from the makers.

The Oil-ways

Before an old bearing is stripped of its white-metal prior to re-metalling, a careful note should be made of the disposition and nature of *the oil-ways.* The latter should be reproduced on the re-metalled bearings, after a preliminary scraping in and before the final scraping in. The pattern of the oil-ways should be pencilled out on the metal, and the latter cut away with a round-nosed chisel. After the chiselled grooves have been smoothed out with a suitable half-round scraper, the edges should be carefully radiused all the way round, as shown in Fig. 382. The rule to adopt in connection with oil-ways is continuity from the oil lead in and absolute smoothness throughout; avoid abrupt changes of section and sharp corners. The oil should be led in on the lightly loaded side of the bearing; the oil-ways may cause a break in the oil film on the heavily loaded side.

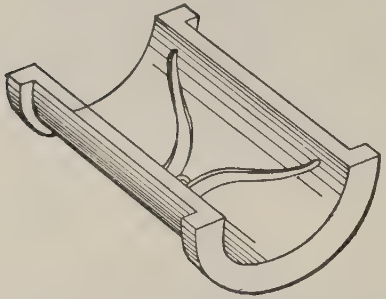
Fig. 382.—The Bearing Oil Grooves.

Finally, *never use emery paper* on any part of a white-metal bearing, not even for the oil grooves; for the hard particles of the abrasive will become embedded in the soft metal and cause the bearing to act as a grinder or "lap" on the journal.

A Bearing Oil Grooving Machine

Whilst the method of cutting oil grooves in a bearing by hand gives satisfactory results, it is apt to be relatively slow in cases where numbers of bearings have to be dealt with, as in routine servicing operations. In such cases it is advisable to employ a special machine, such as the Buma oil-way one shown in Fig. 383. This is a hand-operated pedestal machine, in which bearings of any size used on motor-vehicle engines can be clamped. Oil grooves of any pattern can be machined with the cutters provided by using special cams or plates supplied.

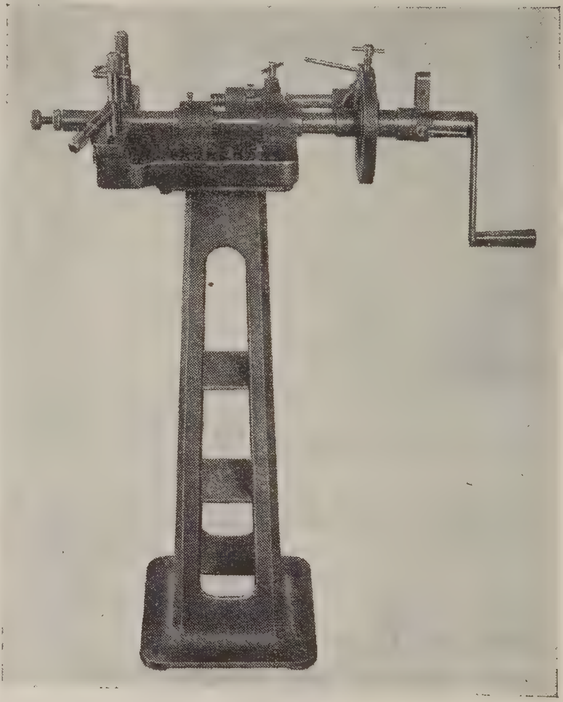
Fig. 383.—The Buma Bearing Oil Grooving Machine.

Bearing Metals

The material used chiefly for big-ends and crankshaft bearings is one of the *white-metals*, specially selected so as to give good wearing qualities, great resistance to compression, a very low friction coefficient, and a sufficiently high melting-point to enable it to withstand ordinary working temperatures.

The best white-metals are those containing a *high tin content*; they are therefore the most costly, so that attempts are sometimes made to foist other bearing metals on the user.

A typical bearing metal possessing all of the desirable characteristics is as follows: tin, 83·3; antimony, 8·3; copper, 8·4 per cent.; this is approximately the composition of the original anti-friction metal introduced by Sir Isaac Babbitt, and now universally known as *Babbitt metal*.

The Admiralty white-metal specification is as follows: tin, 86·0; antimony, 8·5; copper, 5·5 per cent.

A typical composition is: lead, 80; antimony, 14; tin, 6 per cent.

For motor engineers who desire to re-metal their own bearings—and it certainly pays to undertake this work—it is better not to attempt to make one's own bearing metal, but to purchase it from one of the long-established firms of bearing-metal specialists, such as Messrs. Hoyts, Putney (London), Delta Metal Co. (London), and J. H. Richards (Birmingham), stating the exact purpose for which the metal is required.

Moulds or Jigs

We have already described a number of suitable moulds for big-end and main bearings which are on the market, but in the present remarks propose to supplement these with a few descriptive notes[1] on home-made moulds.

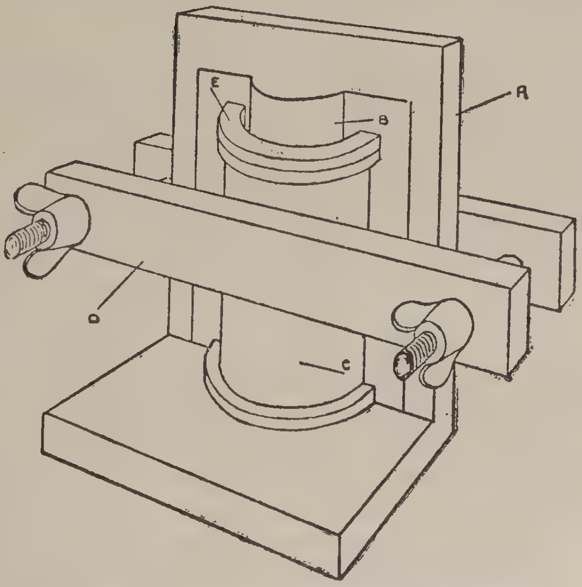

Fig. 384A.—A Suitable Jig for casting Half-bearing.

The mechanic will find the jig illustrated in Fig. 384A, and which is very easy to make, suitable for half-bearings. In this illustration A is an angle plate; B a half-mandrel; and C the bearing shell held in position by a clamp, D. A half-ring, E, is laid on the top of the shell to allow the bearing metal to be built up over the flange at the top.

[1] Representing practice recommended by Messrs. Metal Co., Ltd., London, S.W.15.

The half-mandrels, in appropriate sizes, can be made from sheet steel shaped around suitable diameter tubing. Alternatively, a set of mandrels can be made from bar, or thick steel tubing, drilled and tapped to receive a set-screw passed through the back of the jig.

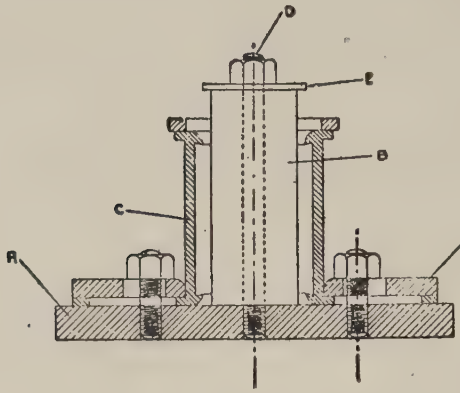

Fig. 384B.—A Re-metalling Jig for Bearings.

Fig. 384B illustrates another jig for re-metalling or lining two half-bearings at the same time. Here A is a plate, fitted with a stud, D, and tapped to take studs holding the clips, F. B is a hollow mandrel, held in position by the stud and nut D and piece E (say, $\frac{3}{4}$-in. by $\frac{3}{16}$-in. steel strip). The half-bearings C are clamped together with a suitable clamp, and attached to the plate with clips, F, the latter being slotted for adjustment. When using a jig of this type, the two halves of the bearing should be separated by pieces of sheet steel placed between the butt faces.

Notes on Metal Heating and Pouring

It is important not to overheat the metal in the melting-pot; for this reason a thermometer should be employed.

Each grade of bearing white-metal has its particular melting and pouring points. Thus, Hoyt's No. 11 metal, which is much used for automobile bearings, pours at 330° C. for small bearings and at a maximum of 430° C. for large bearings. The I.C.E. grade pours at about 320° C.

The metal should be well and frequently stirred whilst in the pot. It is best to use a melting-pot with enclosed gas burner, rather than an open one, to ensure more even heat distribution.

Always have a fair quantity of metal in the pot and, if it has to be kept hot for any length of time, it should be covered with a thin layer of powdered charcoal, to prevent oxidation.

When pouring the metal, the procedure recommended is as follows:

The bearing should be mounted upright in the jig, and the jig, bearing, and mandrel then heated until the tinning on the inner surface *just* runs. Care must be taken not to allow the flame from the blow-pipe to play on the tinned portion, the result of which would be a film that prevents the white-metal adhering when poured. Take care not to make the jig too hot. Heat the ladle before use.

When commencing, pour slowly at the first to avoid wastage through leaks (should the packing be loose anywhere) and also to drive out the air from the bottom of the bearing. Fill the bearing as high as possible.

Do not throw the metal in, but hold the ladle near the job, *at one place*, and gently tilt it so as to obtain a steady flow.

To ensure smooth casting and to avoid blow-holes: immediately the bearing is full, take a piece of clean steel wire and dip it *continuously and rapidly* in and out, all round, lightly and without forcing. At the same time prevent the metal at the top from setting by means of a gentle heat from the blow-pipe E (Fig. 385). The metal at the bottom F will solidify first, and will gradually rise in the direction of the arrow to G. Finally, the metal will be solid up to the top, which can be finished off clean and smooth by means of the blow-pipe. Take care not to pierce metal that is thickening with "venting" wire; this leads to air cavities. During this operation of "venting" (which takes, say, two or more minutes, according to size of bearing), the metal may sink down from the top; if it does, a little more should be poured on.

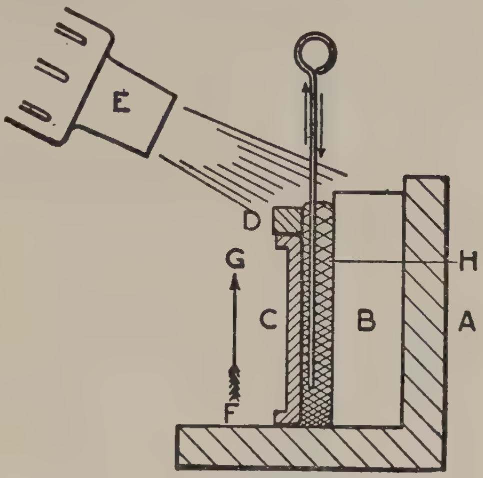

Fig. 385.—Heating the Molten Metal to Prevent Setting.

Cool the bottom of the bearing with cold air from the blow-pipe *as quickly as possible.* If cold air is not available, a wet sponge or cloth may be pressed against the lower part of the bearing, care being taken that damp or water does not reach the molten white-metal inside the bearing.

Fig. 385 shows a half-ring at D. This ring is laid on the top of the shell to allow the metal to be cast higher than the bearing itself, so that the shrinkage on cooling shall take place in the metal to be cut off and not in the metal to remain in the bearing.

A is an angle plate forming the main part of the jig; B a mandrel or core; C the bearing; and H the white-metal between the mandrel and the bearing shell.

Non-adhesion of the White-metal

If the metal does not adhere to the shell after careful tinning, there are no other reasons than the following: (1) the flame has reached the tinned surface and oxidised it; (2) the shell has been made too hot and the surface oxidised in this way; (3) the shell has not been made hot enough to cause the tinned surface to *nearly* run; or (4) the metal has been poured too quickly. Non-adhesion may also be present in bearings filled solid (i.e. without use of a mandrel), due to the metal having shrunk away from the shell on cooling.

Pouring in the Vertical Position

It is desirable that all bearings be filled in an *upright* position, which enables better control of cooling, permits of ventilating, and lessens the liability to blow-holes and shrinks.

When a bearing must be filled lying down, the white-metal may not always fill right up to the extreme edges and into the corners, and will have to be tempted right over the edge with the " puddling " wire. A perfect union will result, with the white-metal snug up to the edge of the bearing; and when it is finally machined, there should be nothing to indicate the union except a change of colour.

Ringing of Bearings

Lined bearings should ring true when touched with a light wooden object. If they do not, the white-metal is not adhering everywhere, and must be run out. Shells impregnated with oil, or cracked, and sometimes those with a lot of holes or grooves, may never " ring " sound, and discretion must then be used. It is well to sound all shells *before filling*, and to mark those that do not ring well, as, of course, a shell that does not ring when empty of white-metal will certainly not do so when full, there being much less " ring " in anti-friction metal than in gun-metal or bronze.

Mould-sealing Compounds

When a bearing is to be re-metalled, it is essential that no places of leakage for the molten metal are left; otherwise a good deal of trouble and loss of time may be caused. Oil-holes, joints, and other likely sources of leakage should be sealed with a plastic composition or clay. Asbestos meal mixed with clay and water, or asbestos millboard made into a pulp with water, form suitable packings or lutings to prevent leakages. The stopping should be well dried with a blow-lamp when in place. Ordinary clay or putty can be used in emergency.

Main-bearing Boring Machine

Special machines are available for boring out, to a high degree of precision and surface finish, the re-metalled main bearings of automobile engines whilst in position in the cylinder block—where the main bearings are carried at the lower part of the block casting—or in the crankcase in instances where this carries the bearing housings.

These machines can be obtained either for hand operation or power drive (electric motor). They are provided with automatic alignment devices and with automatic feed for the boring-bar tools.

The hand-operated Cuthbert machine clamps on to the cylinder block when the latter is placed upside down. It employs adjustable steadies, which can slide up and down vertical round bars, similar to those shown for the power-driven machine in Fig. 387. It uses a rigid-pattern boring bar with holes along its length to take the cutters in the positions required. These are usually of the tungsten-carbide type, and of shapes suitable for line boring, radiusing or end facing. The machine has an automatic feed for moving the tool along the bearings. It works on the ratchet, pawl, screw, and nut principle.

Alignment of Boring Bar

An important operation when setting up main-bearing boring machines is that of the central and longitudinal alignment of the boring bar in the bearings. Unless the bar is correctly set up it will machine either eccentrically or out-of-line with the machined face of the cylinder block, so that the crankshaft will no longer be at right angles to the cylinder barrel axes.

Each design or make of boring bar is provided with means for adjusting the boring bar dead centrally in the bearing housings and checking the position of the bar. In some cases locating conical members are provided which fit over the boring bar and enable the latter to be adjusted in relation to the end bearings, into which the sliding cones fit, for location. These cones are removed after the boring-bar adjustable supports have been tightened down by their bolts and nuts. Afterwards a final check should be made, using a dial gauge and V-block or half-shell unit which can be located on the boring bar (Fig. 386).

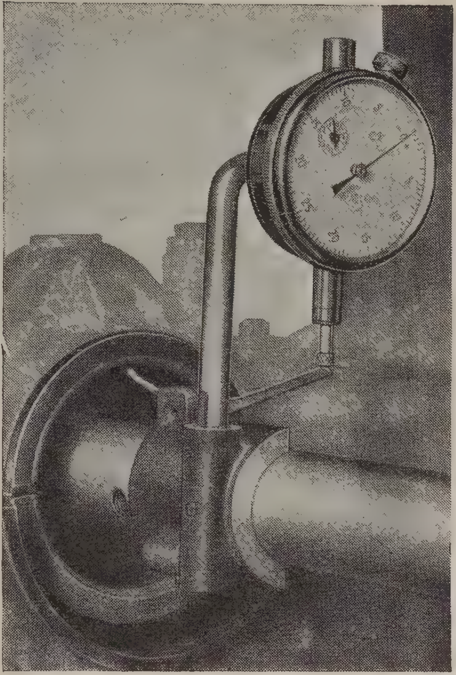
Fig. 386.—Checking Boring Bar for Concentricity with the Bearing (Buma Machine).

In some instances a light " pilot " cut is made through the end bearings to check the accuracy of the boring-bar alignment.

Alternatively to the use of cones for locating the boring bar, half-sleeves can be used between the boring bar and the bearings.

Typical Main-bearing Boring Machines

In the Cuthbert machine (Fig. 387) in order to locate the boring bar and ensure the correct alignment of all the main bearings, special cast-iron cylindrical jigs or formers are supplied. There are two such jigs, one for each end bearing, machined externally to fit the front and end main bearings and bored internally to take the boring bar, a gauge or sliding fit being arranged for this purpose. The boring bar is then located by first clamping the jigs in the end bearings and then adjusting the two end intermediate steadies so that the boring bar is a sliding fit in them. The end bearing jigs are then removed and the bearings are ready for boring. The steadies thus form an effective jig for the bearing machining operations.

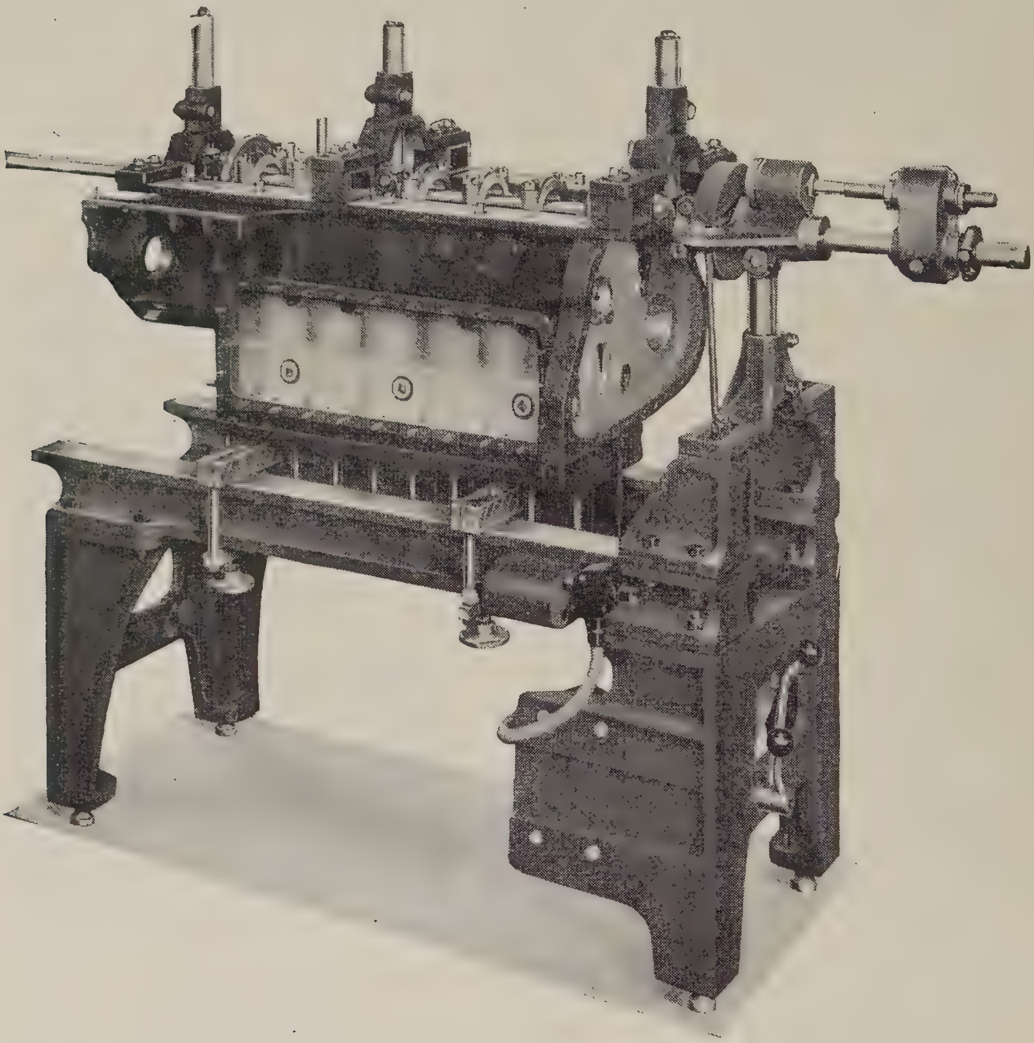

Fig. 387.—The Cuthbert Power-operated Main-bearing Boring Machine.

When the reversed cylinder block has been mounted on the cross-pieces of the machine a clamping strip is bolted to each crankcase flange. These carry the bridge pieces which, with the pillars and swivel heads, form the steadies. Usually two end steadies and one intermediate steady are used for the boring operation.

The clearance of the boring bar in its steadies is ·001 in., i.e. ·0005 in. on the radius, and if properly adjusted so that the boring bar can slide easily in an endwise direction this ensures entirely satisfactory alignment.

In this power-driven machine a ½-h.p. electric motor is employed, the drive to the boring bar being taken by an endless belt to a countershaft and thence to a pulley in the driving head. An automatic gravity-controlled jockey pulley device is employed to maintain constant belt tension; with this unit there is no belt strain on the boring bar. The drive head incorporates the same type of swivel mounting as for the steadies, so that there is no difficulty in using the head on sloping crankcases. The drive head is bolted to the body of the machine and embodies a sleeve mounted in bronze bearings, which carries at one end the driving pulley and at the other the driving ring. This is detachable so that the bar, which passes through the sleeve, may be withdrawn in any direction. A specially-designed feed box is used. This unit is detachable and is only placed in position when the setting up is completed. Power-feed, hand-feed, and rapid power traverse are available. A selector thumbscrew is employed for selecting the feed. A much finer feed can be used than in the hand-operated machine. The speed of the boring bar is 350 r.p.m. and the rate of power feed ·005 in. per revolution of the bar. A special micrometer is provided for precision setting of the radius of the boring tool.

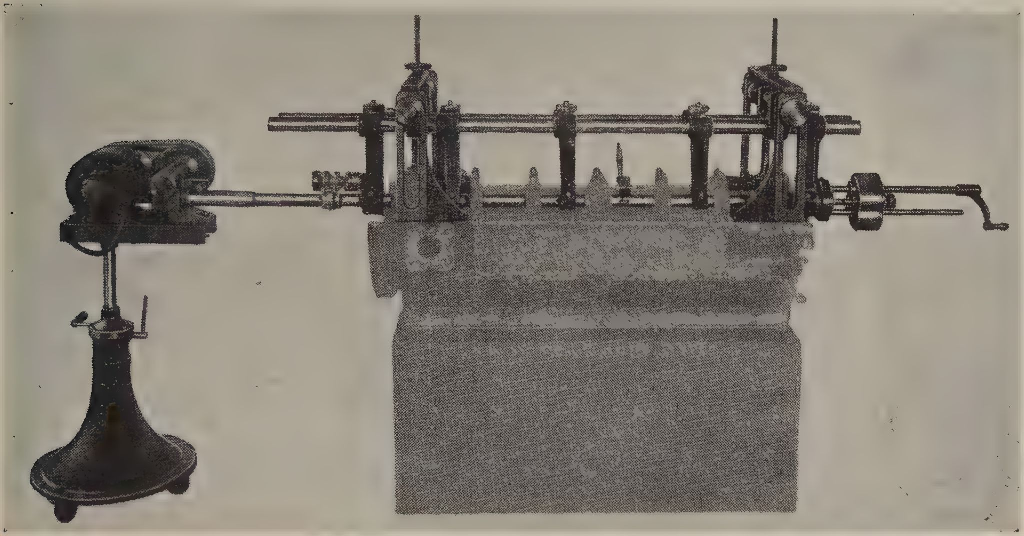

Fig. 388.—The Buma Main-bearings Boring Machine.

The Buma main-bearing boring machine (Fig. 388), which is based upon the design of a prototype machine used for several years at the manufacturer's works on all types of engines, is of the positive-location power-driven type. It has four corner supports, which bolt down on to the reversed cylinder block, and a number of steady arms for supporting the boring bar in a rigid manner; these arms are adjustable in all directions and can be locked securely once the boring bar has been accurately aligned. The principle of the method used for the boring-bar supports is that of two rigid parallel cylindrical bars which form the supports for the steady arms holding the boring bar below. The machine is set up by placing it on the reversed cylinder block and threading the boring bar through the main bearings. The bar is then centred and held in position with the aid of setting cones and holders. After bolting the support brackets to the crankcase and tightening the clamp nuts on their spherical seated sleeves, the machine is fully self-aligning and it is only necessary to tighten the clamp screws which control the side float. The setting cones are then removed, and a final check for alignment accuracy is made with the dial-gauge fitting which is used on the boring-bar surface (Fig. 386). A turn of the handwheel clamps each steady on the overhead bars.

The boring bar is rotated from the $\frac{1}{4}$-h.p. electric motor, which is mounted, adjustably, on a pedestal unit. The mounting consists of a moving platform mounted on rollers. Fixed to the platform is the motor, worm-drive gearbox, and a double universal joint for coupling to the boring bar. Provision is made for driving the boring bar at two different speeds. The feed box has a coarse-thread Acme screw for quick return of the boring bar. The ordinary machining feed is ·003 in. per revolution. A diamond-bonded wheel is supplied for sharpening the cutters.

Filling Bearing-cap Faces

When bearings have been re-metalled, it almost invariably happens that the faces of the caps are left uneven, due to the irregularity of the bearing metal which has been poured in. One of the operations on these caps, before boring, reaming, or scraping, is to true up these faces (Fig. 389).

If the surfaces are not filed truly, when the two halves are bolted together they will bear only on one or two spots, and in time the bearing may become slack in fit due to this cause. Again, the bearings will not "pull-up" correctly if the two surfaces of each half-bearing are not accurately trued.

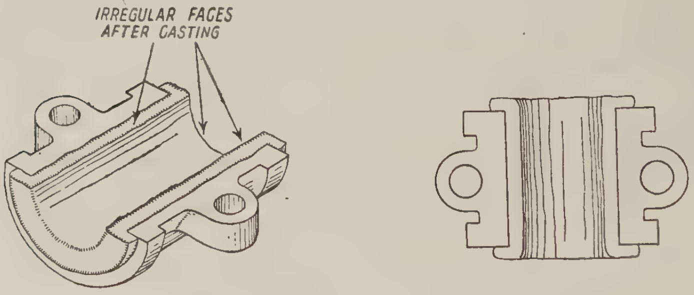

Fig. 389.—Appearance of Bearing after Re-metalling.

It is better to use a filing fixture in cases where many of these bearings have to be fitted, as, for example, with Ford, Morris, and similar engines.

Notes on Lining Bearings

The following practical notes are merely intended to supplement the information already given, and to include some useful workshop hints and methods.

When a connecting rod or main bearing has to be relined, the old metal should be run out by just heating the shell sufficiently for this purpose; the shell should be wiped with a cloth whilst hot.

In the case of a new bearing which has to be lined for the first time, it is important to tin thoroughly that part of the shell which has to hold the white-metal. All grease, dirt, and other extraneous matter should be eliminated.

A high-quality tinman's solder should be used; otherwise the bearing metal, which has a high tin content, will not adhere properly. The soldering compound " Soldo," or the later compound known as " Soltic," which contains the finely divided tin and its flux in a powder form, is very satisfactory for tinning bearings, for it is unnecessary even to clean the shells of dirt or grease.

If the shells are heated to the melting-point of the compound, the latter may be sprinkled on, and then rubbed over the surface with a soldering iron or a piece of wire. The shell is then wiped with a clean cloth to get rid of the dross, when a perfectly tinned result is obtained; the white-metal will amalgamate quite satisfactorily with this tinning.

After ordinary tinning, using a good flux, such as zinc chloride (" killed spirits," made by dissolving as much zinc as possible in hydrochloric or muriatic acid), the bearing should be wiped with a clean cloth and then given a liberal coating of solder again. After running out an old bearing, re-tin it; do not rely on the previous tinning.

Scrapers for Bearings

The use of the correct design of bearing scraper enables the work to be done both quickly and efficiently. Whilst excellent scrapers can be made out of worn-out files, the best ones are those supplied for their particular purpose. The most widely used scraping tool is the half-round one with tapering and curved point, as shown in C and D, Fig. 390. The three-square scraper (A) is another useful tool for finishing purposes and for smaller bearings.

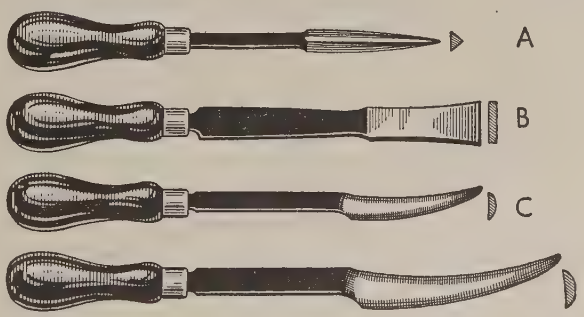

Fig. 390.—Types of Bearing Scrapers.

The flat scraper (B), as its name implies, is used for scraping down flat surfaces.

The best half-round scrapers are cranked as shown in Fig. 390 (C and D) to allow them to be used with ease in any position; all corners of the scraper which come into contact with the hand are rounded off so that the tool is convenient to handle.

In connection with the general design of scrapers, including those made from old files, it is recommended that clearance grooves A (Fig. 391) should be made in these, in order to reduce the widths of the scraping surfaces, and thus facilitate re-sharpening; in this case the area of blade to be ground or oil-stoned is much reduced.

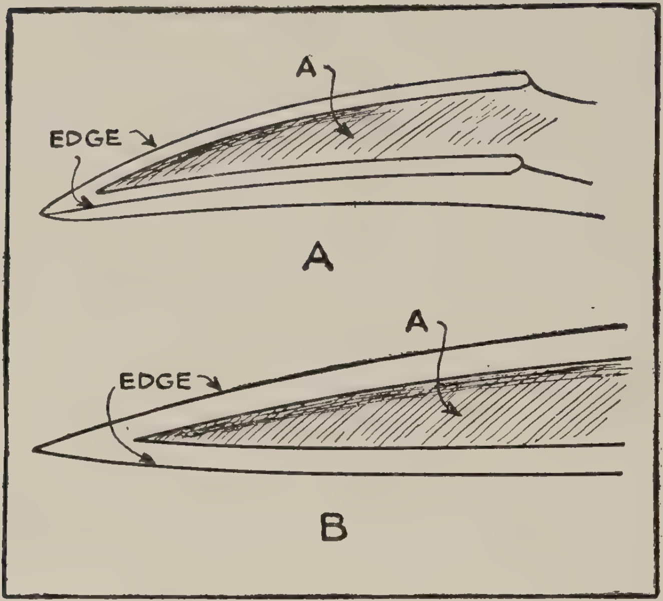

Fig. 391.—Showing Method of reducing Area of Cutting-blade Surfaces by grooving the Scraper at A. A—Half-round Scraper. B—Triangular Scraper. These can be made from old files.

White-metalling Duralumin Rods

In connection with the white-metalling of duralumin connecting-rod big-ends, it is not an easy matter to " tin " the bearings beforehand (as in the case of steel rods), so that a different method must be adopted. There is another reason why it is impossible to tin the bearings, even if the tin, or solder, could be made to adhere, viz. that the heat necessary for this purpose would affect the "temper" of the metal, thus reducing its strength properties.

White-metal has actually been cast into duralumin rods in some cases, but great care is necessary to avoid overheating the rod. If the big-end portion of the rod be made a little heavier, there is not the same tendency to reduce its strength.

The practice of one firm is to first heat the rods in a lead bath to 330° C., and then to transfer them to a bath of molten tin where a rotating brush slightly larger than the bore of the rod's big-end is used to scrape the bearing surface. The tin then adheres well on to the metal of the rod, so that the white-metal can be poured into place as in the case of a steel rod. Another method which avoids the application of heat is to design and machine the big-ends of the rods so that the white-metal half-bearings can be swaged into position by turning over suitable fins of the rod metal.

In some cases the aluminium alloy used is specially hardened by heat-treatment and is used on the crank-pins direct in the same manner that floating gudgeon-pins are used in aluminium-alloy piston bosses; the special alloys are good bearing metals.

Lead-bronze Bearings

Lead-bronze is an alloy composed of copper, tin, and lead, which is chiefly employed for heavily loaded big-end and crankshaft main bearings of high-speed oil engines; it has also been used on some makes of petrol engine.

A typical composition is as follows: copper, 65 per cent.; lead, 30 per cent.; and tin, 5 per cent.

This bearing metal is much stronger in tension and compression than ordinary white-metal and, as it is capable of taking a high degree of surface polish, its frictional resistance is relatively very low.

Lead-bronze is used as a liner in a steel shell, usually for the top half of the connecting-rod big-end and the bottom half of the main crankshaft bearings, since these are the most heavily loaded ones. The other half-bearings are of white-metal-lined steel or bronze. One other advantage of this arrangement is that should overheating of the bearing occur the white-metal (which has the lower melting-point) will fuse first, and thus tend to increase the bearing clearance, thereby preventing failure.

In the case of the A.E.C. oil engines the big-end bearings are carried in a steel shell and the connecting-rod top half-bearings are lined with a special lead-bronze alloy. Except for a short " mud or sediment groove " at the joint between the rod and the cap, the bearings have a plain surface free from any grooving. Special attention should be given to the fit of these bearings, and they should *on no account whatever be fitted with a smaller clearance than from ·0045 in. to ·0055 in.*

It is extremely important that when replacing the bearings, the lead-bronze half is fitted in the connecting rod and not in the cap.

The surface of the rod and cap must on no account be filed. End play between the rod and crank should be ·008 in. when new.

Ford Bearing Adjustment Procedure

The following is a description of the recommended Ford service procedure for taking up main bearings, and connecting-rod ones also.

Main Bearings.—Any appreciable wear in the main bearings should be, when of the white-metalled type, met by re-Babbitting and reboring. To attempt to take up a serious amount of play by filing down the caps, or even by the fitting of new caps, will not produce satisfactory results, owing to the thinness of the metal left in the bearing. Moreover, it is almost inevitable that the crankshaft will be forced out of line; this will lead to excessive wear on the bearings, and most probably fracture of the shaft.

When checking over main bearings, the first point of importance is to gauge up the crankshaft with a micrometer to see that it is not worn oval. Take measurements across several diameters on each bearing, and if any of the journals or crank-pins show more than ·0025 out of round, a new shaft should be fitted.

If the journals and crank-pins are satisfactory, the shaft should be tried between centres or on V-blocks with a dial indicator, to see that it is running true (see Fig. 375). If it is sprung at all, it should be straightened in a press before being fitted, as replacing a sprung shaft will only result in excessive wear on the bearings and ultimate failure of the shaft.

If the shaft is satisfactory, the bearing metal in good condition, and the bearings themselves not worn oval, slight wear may be taken up by removing one or more of the brass shims from under the cap.

In the first place any raised Babbitt on the cylinder-block bearings should be filed off flush with the top and a 45° chamfer put on (see Fig. 392). This provides an oil groove at each side of the bearing, and at the same time allows space for any slight excess of Babbitt pressed out as the bearing gets run in.

The oil grooves in the rear and centre bearings should then be examined and cleaned out where necessary. The dimensions of these grooves should be as follows: rear $\frac{5}{32}$-in. wide, $\frac{1}{16}$-in. deep, $1\frac{1}{2}$-in. long; centre $\frac{5}{32}$-in. wide, $\frac{1}{16}$-in. deep, 1-in. long. See also that the oil-hole in the front bearing is clear, and that all dirt is removed from the oil pockets. The bearings should then be wiped clean, the shaft smeared with red lead and replaced.

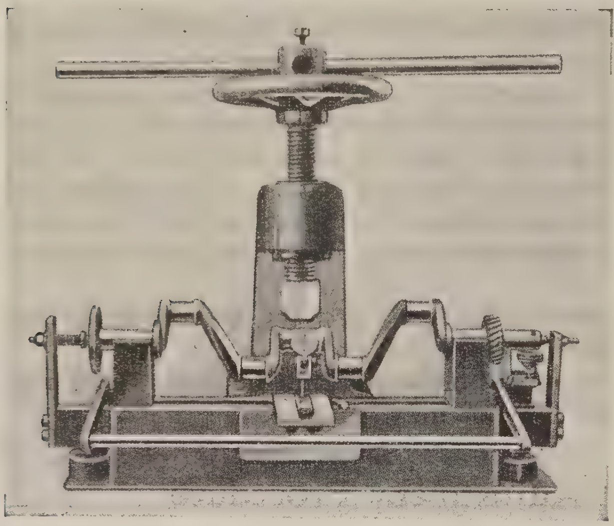

Fig. 392.—Crankshaft Aligner and Straightener.

Test for end play. On a new job this should be ·001 in. to ·004 in.; on repairs up to ·006 in. may be allowed. All tests for end clearances should be made with a feeler gauge.

Fit the rear cap with one less shim than it had originally, pulling down the nuts as far as possible without stripping the threads. If the bearing is a proper fit, the crankshaft can just be turned with one hand. If it is too easy, take off the cap and remove another shim; if too tight, put in an additional shim. When the proper fit has been obtained, remove the cap and observe whether the red "spotting" indicates a good bearing. If not, the high spots on the Babbitt should be removed with a scraper. Refit the cap, turn the shaft and inspect again, repeating until the proper result is obtained.

Fit the centre and front bearing caps in the same way. When the proper adjustment of all three bearings has been effected, it should be possible just to turn the crankshaft with both hands. Then remove the caps and shaft, clean the Babbitt surface carefully and smear oil on bearing, cap, and crankshaft. Refit the caps, drawing up the nuts as tightly as possible, and cottering.

It is very important that the bearings should be oiled before the shaft and cap are replaced, because if the engine is started up with the bearings dry, the Babbitt is likely to seize up to the shaft before the oil in the crankcase has had time to work through.

Connecting-rod Bearings.—If the metal in the rod and cap has not been damaged in any way and the crank-pin is not more than ·0025 in. out of round, slight play may be taken up by filing the cap.

Great care must be taken to hold the file squarely on the cap. When this has been dressed down sufficiently, try the surface for high spots, either by holding a straight-edge across it at several points and angles, or, preferably, by rubbing lightly on a surface plate.

High spots should be smoothed off with a file until they are evenly distributed over the surface of the cap. The rod may then be replaced, and should be tight enough to require a tap with a hammer to move it along the shaft. Take care to oil the bearings in both rod and cap before finally reassembling the engine, otherwise there is danger of the Babbitt seizing up before the oil can work through.

If the Babbitt has been burnt out, a new rod should be fitted. Care should be taken in such cases to see that the crank-pin is free from any Babbitt left by the seizure; this can be dressed off with an oil-stone. Before installing a new rod or replacing one previously fitted, it should be carefully inspected for alignment, as a rod which is out of line will cause excessive wear and knocking.

In fitting a new rod to an old crankshaft, the crank-pin is usually undersize, and it is not only necessary to remove the paper shims, but also to file off the face of the cap. If the crank-pin is badly undersize, it will be necessary to file both cap and rod and scrape the Babbitt until a 50 per cent. bearing is obtained.

To scrape in a bearing, file the cap and rod until it will tighten down on the shaft so that the rod cannot be moved by hand, then loosen the bolts just sufficiently to allow the rod to be turned, and work it backwards and forwards a few times. Remove the cap. The high spots on the bearing will show, and should be removed with a bearing scraper. Scrape very lightly, as deep holes are hard to smooth out. A very thin coating of Prussian blue wiped on the shaft before trying out the bearing will show up the high spots more plainly.

When the rod shows a good bearing of about 50 per cent., replace on the shaft after oiling and tighten up the nuts. It should then be just possible to turn the rod by hand. Assemble the motor, with the exception of the lower cover, and start up. Run for about 30 seconds, and then remove the cap and examine the bearings. Remove any loose Babbitt and, if otherwise satisfactory, oil and replace. If the bearing is not good, file a little more off the cap and continue scraping until satisfactory.

If the crankshaft is oval or badly undersize and all the rods need replacing, it is usually less expensive to put in a new crankshaft.

Big-end Oil Jet

In many modern designs of engine, lubrication of the cylinder barrel is made more positive by arranging for a jet of oil to escape from the pressure-fed crank-pin supply through a hole drilled in an oblique direction through the connecting-rod upper bearing-cap housing. This assists cold starting, cylinder lubrication, and ordinary running conditions.

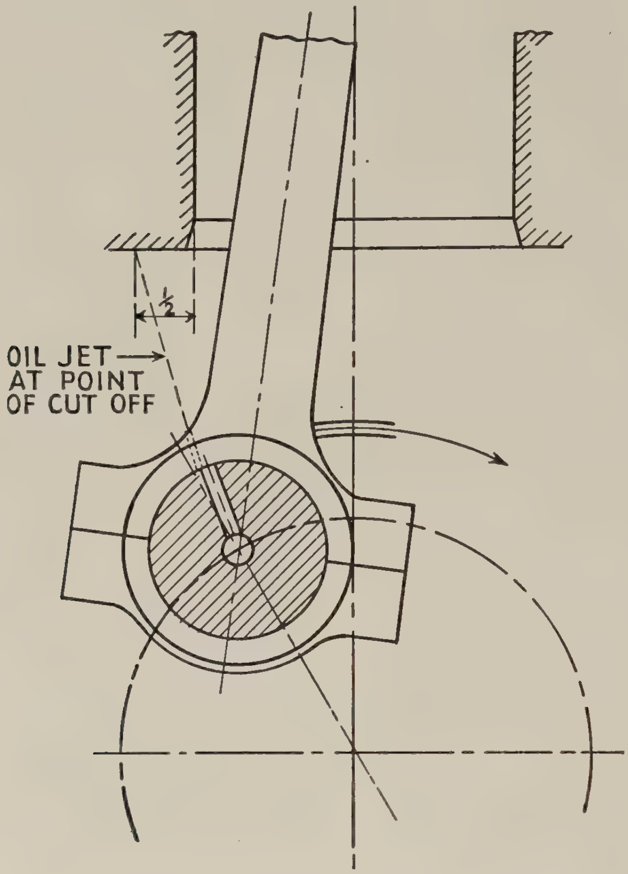

Fig. 393.—The Oil-jet Method of Lubrication.

Once every revolution, the holes in the crank-pin and connecting rod come opposite to each other, when oil under pressure emerges as a jet and impinges on the lower-edge cylinder wall reached by the piston skirt. Fig. 393 shows the method recommended by the Birmingham Aluminium Casting Company for this purpose. It will be observed that the location of the two holes must be correct, otherwise the oil jet will not reach the cylinder wall. If the jet impinges inside the piston it will be ineffective; similarly, if it strikes the base of the cylinder casting. The hole through the connecting-rod bearing and its housing should not exceed $\frac{3}{64}$ in.

CHAPTER II

THE CRANKSHAFT, FLYWHEEL, AND OIL SEALS

Some General Considerations

THE modern motor-vehicle crankshaft, which is made of a high-tensile alloy steel, is subjected, in service, to severe stresses or loadings as well as wearing action, so that eventually it is necessary to remove and inspect it.

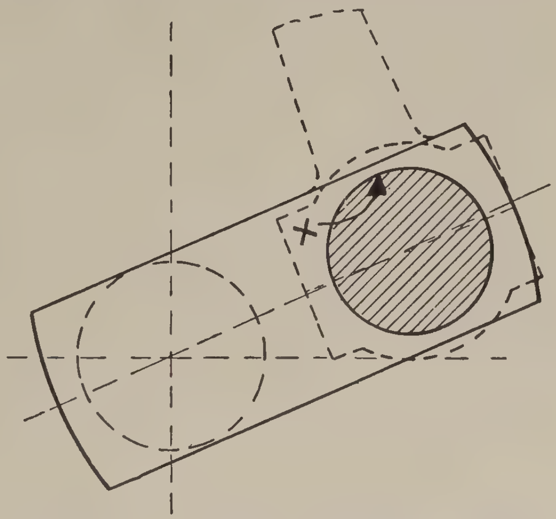

Fig. 394.—Showing Position of Crank for Maximum Thrust Load on Crank-pin.

It is possible to predict the type of wear to be expected in the case of the crankshaft big end and main journals, by considering the manner in which the loads on these bearings vary during each engine revolution. If this is done, using connecting-rod thrust diagrams, which can be drawn from a knowledge of the cylinder-pressure variations and the connecting rod to crank ratio, it will be found that in all but very high-speed engines the greatest load occurs during the early part of the firing stroke, at about the connecting-rod crank position shown in Fig. 394. Again, during the compression stroke the crank-pin will exert an increasing pressure on the same part of the bearing, at X, with the result that the bearing and crank-pin will on this account be subjected to more wearing action over the region AXB (Fig. 395) than on the rest of the surfaces.

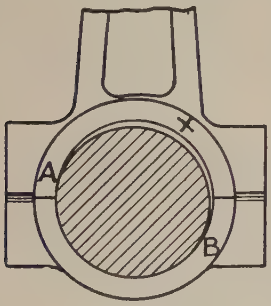

Fig. 395.

In the case of high-speed engines there is another loading factor, namely, that due to the weight, or inertia, of the piston and connecting rod, which may modify the cylinder-pressure loadings and produce a quite different loading during each revolution.

In most car and commercial-vehicle engines it is found that the crank-pins after much service—usually 40,000–50,000 miles for car engines—have worn out of round, i.e. are roughly oval in shape. In addition, scores are sometimes found; these are due to dirt in the oil passing into the bearings. Occasionally, too, the crank-pin may be found to have worn slightly tapered.

The general procedure when the crankshaft is taken out of an engine is as follows: (1) degreasing or cleaning; (2) visual examination for journal scores or matt marking; (3) checking for bent crankshaft; (4) measurements of the journal diameter with outside micrometer calliper or crankshaft gauge. In the routine servicing of crankshafts it is usual to test the whole of the surface for the presence of minute cracks, known as fatigue cracks, using for this purpose an apparatus known as a *crack detector*. If any cracks are found the crankshaft should be discarded, since such cracks are indications of the initial stages of failure of the crankshaft.

In regard to the main-bearing journals, whilst these are also subject to a variable loading and tend to wear more around the top and bottom centre positions, the amount of such wear is generally not so much as for the crank-pins.

Crank-pin Truing Dimensions

Should the crank-pins be found to be scored or worn more than about ·002–·003 in. oval they will need truing by any of the available methods, such as turning, grinding, or honing described in this chapter. Information on the correct truing sizes or diameters is given later. It should, however, be stated that when solid white-metal big-end bearings are employed in an engine it is necessary only to true the crank-pin to cylindrical shape and with a good polished surface finish. When shell-type bearings are employed it is then essential to true the crank-pins to definite (undersize) dimensions to suit the (undersize) replacement bearings available.

Crank-pin Truing Methods

The methods available for truing crank-pins—and main journals in most cases—may be classified as follows:

(1) Hand-truing methods, using files and laps.

(2) By the use of hand-operated crankshaft truing tools employing fixed cutters and guides.

(3) By means of a honing tool with suitable guides.

(4) By the regrinding method, using portable or fixed machines.

(1) Truing Crank Journals by Hand

It is possible to true up worn journals without the use of expensive or elaborate plant, provided one has the necessary skill and patience. The only accessory required is a micrometer or accurate calliper gauge.

The journal is first measured across several diameters in order to ascertain whether it has worn " tapered " or " oval." It is possible, by the careful use of a smooth file and emery cloth, to reduce the larger diameter areas until the journal is practically round and is also parallel. Next, a lapping arrangement similar to that shown in Fig. 396 is applied to the journal. The two halves of the laps may be made of brass or copper; lead can also be used, provided that it is sufficiently thick so as not to alter in shape.

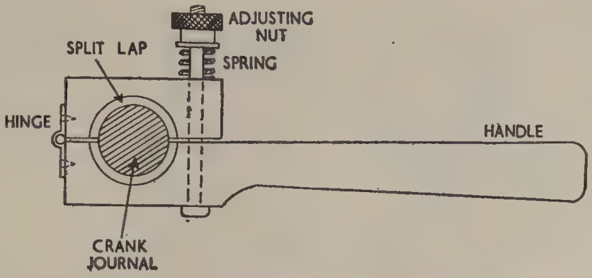

Fig. 396.—Hand Lapping Device for Crank Journals

For the most accurate results the lap should be made from a lead, brass, or copper cylinder turned to suit the journal diameter and afterwards sawn diametrically into two equal halves.

Another alternative, and one that has often been used in the past, is that of using the connecting rod itself, with an old pair of white-metal bearings as a lap. Where the engine is one of a mass-produced car, an old connecting rod can often be procured and used for lapping purposes. A handle should be fixed to the small-end portion of the rod to facilitate the holding of the rod during lapping operations.

A very fine grade of emery powder, e.g. FFF or 180 grade, is used in the lap; a good supply of oil is necessary. The crankshaft should, preferably, be mounted in the lathe, and driven around for this purpose. The split bearings should have end flanges or pins to prevent side movement when lapping.

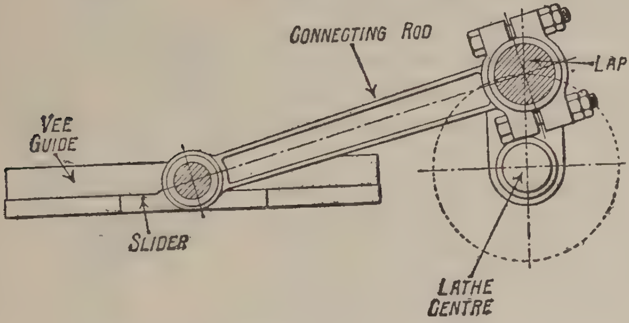

Fig. 397.—A Useful Slider Lapping Device.

With a little ingenuity a simple form of slider device (Fig. 397)—corresponding to the cylinder and piston of an engine, with a connecting-rod attachment—can be used to lap the crank-pins in the lathe, whilst the crankshaft is centred on its main journals. The better method, however, is to offset the main journal centres so that the crankshaft rotates truly about the centre of the crank-pin being lapped; no slider and guide is necessary in this case.

(2) Crankshaft Tools

A neat and effective type of crankshaft truing tool is that illustrated in Fig. 398A; it is known as the K.B.

The tool carries four radial pieces in a cast-iron frame, split and bolted together. Of these four pieces, one only is a cutter, and the three others dummies or guides. The latter and the cutter are moved independently by a hardened screw, operated by a key, and can be adjusted to deal with any journal from 1- to $2\frac{3}{8}$-in. diameter. Journals of different lengths can be dealt with by moving the tool endwise while cutting, and suitable radii are supplied on the cutters to suit the crank-pin fillets.

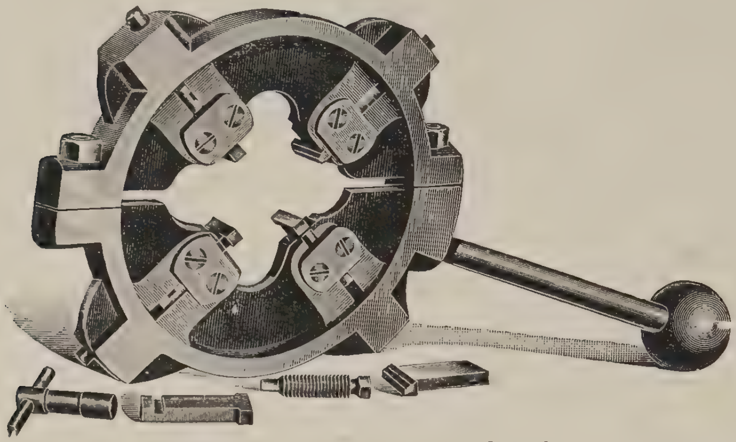
Fig. 398A.—The K.B. Crankshaft Tool.

The cutter is prevented from following the contour of the worn crank-pin journal by the guides and from cutting taper by means of the hardened and ground-steel plates on the casting against which the cutter and the guides are pressed by means of stiff spring plates; they slide firmly in contact with these hardened plates. The three guides are truly radial, but the cutter slot is offset behind its centre line so as to avoid any digging in of the tool. It is claimed that the K.B. crankshaft tool will true any crankshaft journal to within one-quarter of one-thousandth of an inch, i.e. ·00025 in., and remove all taper within one half-thousandth inch at an average time of twenty minutes per bearing.

The B.T.S. crankshaft truing tool shown in Fig. 398B has three guides and one cutter unit. It is made in two parts, which are hinged on one side so that the tool can be opened out for placing around the crank-pin. It is then closed and secured in position by the knurled screw shown on the left.

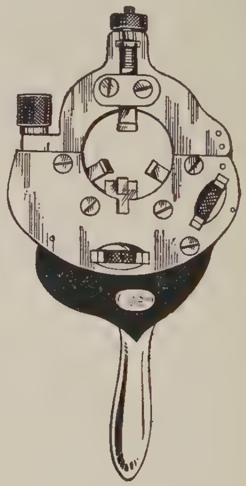
Fig. 398B.—The B.T.S. Crankshaft Tool.

The tool has two screw-adjusted steadies and one automatic steady which is operated from the handle; as pressure is applied to revolve the tool around the journal, it automatically tightens the steady on to the journal. The cutter has a milled-head nut and screw adjustment for diameter control.

Another crankshaft tool, known as the Ammco, is shown in Fig. 399. In this case there are two contact planes at right angles. The cutter has a fine adjustment operated by the large milled screw shown on the left.

A more recent precision crank-pin truing tool is the Arnott one shown in Fig. 400. It is made in two models (A) and (B.) These embody a special cutting tool and a V-shaped steady or guide to align the cutter to the crank-pin. A fine adjustment is provided so that the cut can be regulated to within one half-thousandth inch; in one model the differential-pitch screw method of fine adjustment is employed.

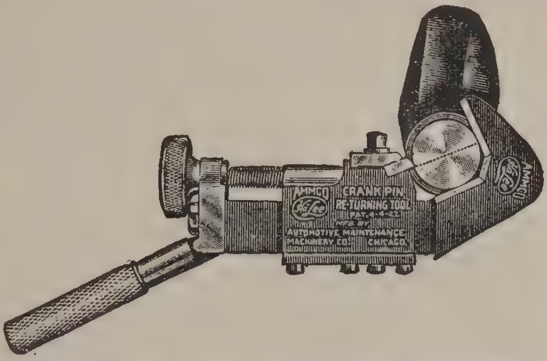

Fig. 399.—The Ammco Tool for Truing Crankshafts.

Referring to the tool shown at (A), the tool holder and adjustment block have stud portions which move in the slotted body of the tool. When the securing nuts are slackened the tool holder can be moved towards the shaft journal until the tool just touches it. The adjustment block with its regulating screw device is then brought up to make contact with the tool block and is locked in this position by means of its nut; the tool holder is also locked. To increase the cut the tool holder nut is slackened and the adjusting lever moved around. A movement of one-third of a complete turn provides a forward feed of one-thousandth of an inch.

The model shown at (B) is of simpler design and is arranged so that it can be manufactured by turning operations only, instead of milling ones. The actuating mechanism is enclosed within the hollow spindle of the tool.

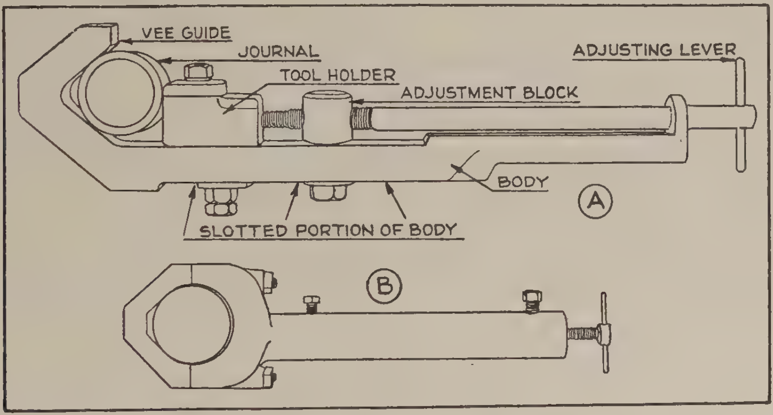

Fig. 400.—The Arnott Crankshaft Truing Tools.

The Arnott tool is also designed for attachment to the underside of the crankcase, by means of two rigid pillars with crossbar stay having a swivelling block with a hole through which the guide bar of the tool can slide as the crankshaft is rotated by hand. Thus the journal can be trued without removal of the crankshaft from the engine.

Another accessory is a double V-block and bed unit to which the crankshaft is transferred for bench truing operations. It employs a fixed bracket and trunnion for the guide rod.

(3) Truing Journals by Honing

It is now possible to correct ovality and taper in crankshaft journals with the aid of a precision honing tool, either in position in the engine—for crank-pins—or on a lathe for main- and big-end journals.

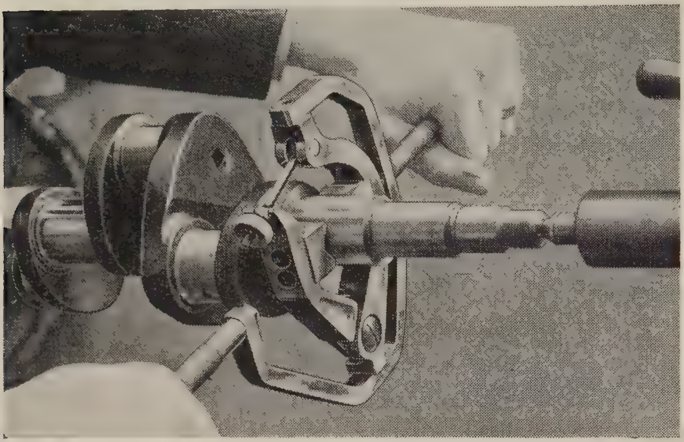

Fig. 401.—The Delapena Journal Hone.

The Delapena tool shown in Fig. 401 envelops the journal to be trued, and whilst the crankshaft is rotated at about 60–70 r.p.m. pressure on the hone is applied by means of a milled-screw adjustment. The tool is then moved slowly from side to side of the journal. As metal is removed from the journal the adjusting screw is tightened until the journal is rendered truly cylindrical and to the correct diameter; it is possible in this way to true a journal to within less than ·001 in.

Where an appreciable amount of stock has to be removed a coarser stone is fitted, whilst for finishing purposes a fine grade of stone is employed. It is advisable to remove and reverse the tool on the journal during the honing operation in order to equalise stone wear. The honing tool is provided with different sizes of steadies and hones, and has a range of 1–2½ in. diameter. By using the correct grade of finishing stone a high degree of surface finish or polish can be obtained.

(4) Grinding Crankshafts

No doubt the most satisfactory method of truing crankpins and journals is that of grinding, for not only are the results extremely accurate, but the surfaces are left in a very clean condition for the bearing metal to bed upon. Owing to the expense of ordinary grinding machines suitable for crankshaft work, only the largest firms of automobile engine reconditioners can afford these, so that unless there is a good deal of regrind work it may be better to employ a grinder attachment for the ordinary lathe.

It is necessary to use a different composition of grinding wheel for the steels used in crankshafts than for cast-iron, and in this respect the manufacturers of abrasive-material wheels will always advise.

The reconditioning of motor-car engine crankshafts after they have been in service for a considerable period is one which requires very careful attention and the use of suitable lathes. The skilful mechanic, given a suitable lathe, can usually rig up a satisfactory arrangement for this purpose, but where a large amount of regrinding is concerned it is advisable to use a special machine.

Checking for Distortion

Before a crankshaft is reground on its main and big-end journals it should be tested for straightness either on a large surface plate, using V-blocks and a dial gauge, or between lathe centres (or those of the grinding machine), using a scribing block having a dial gauge attachment, working on the clean bed of the lathe. In the case of certain engines where there is only one main bearing between two pairs of cranks or in small four-cylinder engine crankshafts with end main bearings only, it will occasionally be found that the crankshaft has become slightly bent.

Bent crankshafts should be straightened in a press, using V-blocks at the ends and a central press-tool fitting.

In connection with the allowable limits of bending at the centre of crankshaft, this will vary with the size and type, but for most four-cylinder crankshafts the maximum permissible amount of deflection, when the crankshaft is supported at each end and measured at the centre bearing, is ·001–·0015 in.

The Bedford six-cylinder vehicle 28-h.p. Model K.M.O. engine has four main bearings, and when the crankshaft is held securely between lathe centres the maximum permissible bend or deflection at each of the two intermediate bearings is ·0015 in.

Regrinding Sizes for Crankshafts

When the crankshaft journals run in solid white-metal bearings and the big-end and main journals have to be trued by honing, machining, or grinding, the question of journal sizes is not important, since, as previously stated, the white-metal bearings can be adjusted and bored or scraped in to suit the journal. In such cases only the bare minimum amount of metal should be removed in order to just clean up the journal to cylindrical shape.

The white-metal half-shell type bearings, being of the non-adjusting type, cannot be used again after the journals have been trued up, so that it becomes necessary to use *undersize bearings*. The manufacturers of modern engines always supply these undersize bearings in definite steps, so that before the crankshaft journals are trued up and finished it is essential to know the nearest undersize bearing dimensions. The *sizes stated for such bearings* in the manufacturers' spares lists are such that they will fit crankshaft journals of the same dimension, with the proper running clearance. Thus if a journal has been reground for an undersize pair of half-shell bearings listed at ·010 in. undersize (in relation to the original standard diameter), then the journal must be ground to ·010 in. smaller diameter than its original size. The manufacturers usually state the actual undersize bearing diameters and allowable limits for same. As an example, the case of the Austin A40 crankshaft may be considered. This four-cylinder engine has three main bearings equally spaced.

The manufacturers supply undersize bearings in two sizes only for the crank-pin and main journal, namely ·020 in. and ·040 in. The following table gives the regrinding sizes of the journals to suit these undersize bearings:

Undersize of Bearing, in.	*Regrinding Sizes*			
	Crank-pins		*Main Journals*	
	Maximum, in.	*Minimum, in.*	*Maximum, in.*	*Minimum, in.*
·020	1·7299	1·7304	1·8549	1·8554
·040	1·7099	1·7104	1·8349	1·8354

It should be mentioned that the new or standard dimensions of the journals are as follows:

Crank-pins—1·7499–1·7500 in.
Main journals—1·8749–1·8754 in.

The maximum and minimum dimensions given are to allow for very small machining dimensional variations, which will not affect the required bearing clearances; they amount only to ·0001 in. in each case.

In other cases, replacement bearings in a range of undersizes are listed. Thus, for the Bedford 28-h.p. six-cylinder engine undersize bearings are available in the following undersizes from the standard or new diameters: ·005 in., ·010 in., ·020 in., ·030 in., ·040 in., ·050 in., and ·060 in. It should be noted that in this six-cylinder engine all four main bearings are of different diameter, the smallest being the front one (2·1035 in.) and the largest the rear one (2·3225 in.), with the usual tolerances for machining variations.

Typical Crankshaft-grinding Machines

Nowadays the majority of crankshafts of engines that have seen some appreciable length of service are reconditioned by the regrinding method and there are many motor firms that specialise in this work sent to them by smaller garages not so well equipped. Among the available crankshaft-regrinding machines are the Intheblok, Prince, Lempco, Sunnen, Churchill, Van Norman, etc. It is proposed to describe some typical machines, although it will not be possible to deal with all of those on the market.

The available crankshaft-grinding machines may be grouped into three main classes, namely: (1) the portable type that can be used to regrind crank-pins in position without removing the crankshaft or the engine from the chassis; (2) the intermediate garage machine-shop type; and (3) the larger production type of grinding machine to be found in the machine shops of crankshaft regrinding specialists. The selection of the most suitable type of grinding machine will depend upon the size of the motor garage and the extent to which it undertakes complete servicing of motor vehicles. In the instance of the smaller garage and motor-repair shops with few facilities for major overhauls, it is the usual practice to send the crankshafts away to specialist firms for regrinding, but where the amount of routine work on engines justifies, the portable type of grinder will soon repay its initial and running costs.

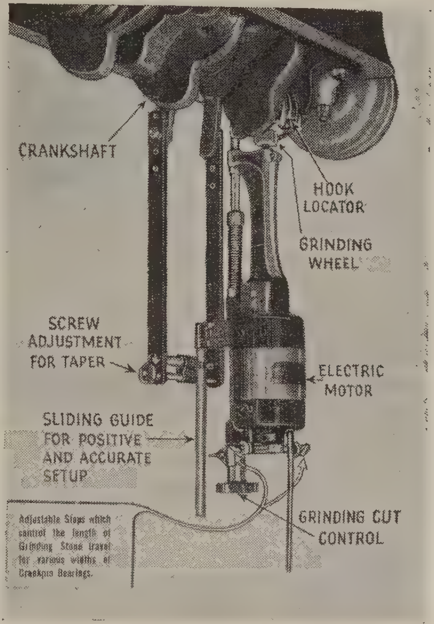
CRANKSHAFT
HOOK LOCATOR
GRINDING WHEEL
SCREW ADJUSTMENT FOR TAPER
ELECTRIC MOTOR
SLIDING GUIDE FOR POSITIVE AND ACCURATE SETUP
GRINDING CUT CONTROL
Adjustable Stops which control the length of Grinding Stone travel for various widths of Crankpin Bearings.

Fig. 402.—The Winona Intheblok Portable Crankshaft Grinder.

The Portable-type Crankshaft Regrinder

This type of machine, of which the Winona Intheblok and Sunnen models are typical examples, has been designed to regrind big-end journals (crank-pins) with the engine in place in its chassis. Alternatively, it can be used with the crankshaft mounted in a lathe, when it will deal with the main journals as well as the crank-pins.

Assuming that the machine is used on the engine in place in the chassis, the sump is first removed, and then the big-end caps, connecting rods, and pistons. The crank-pins are next cleaned, and the machine is mounted on to the first crank-pin. As it is necessary to rotate the crankshaft at a low speed during the grinding operation, it is usual to jack up one of the rear wheels, engage a suitable gear in the gearbox, and drive the rear wheel by means of an electric motor having a friction roller to turn the wheel from its tyre. The grinder has its own independent electric motor. Fig. 402 illustrates the Winona Intheblok[1] crankshaft regrinding machine which employs a small cylindrical grinding wheel that grinds on its end surface and not the usual cylindrical face. This wheel, which is kept trued with a diamond tool and fixture supplied for the purpose, is driven at the correct surface grinding speed, for which the $\frac{1}{10}$-h.p. electric motor unit runs the wheel at 15,500 r.p.m. Whilst the grinding wheel is rotated at this high speed it is brought, gradually, into contact with the journal to be trued. At the same time the crankshaft is being rotated, slowly, either by hand or by means of a $\frac{1}{3}$-h.p. electric motor which has a friction wheel to engage the tyre of the jacked-up rear wheel (Fig. 403). The crankshaft should be rotated at about 12 r.p.m. during the grinding operation. The direction of rotation should be such that the crankshaft should always turn across the stone towards the rear roller assembly, as shown in Fig. 404, which depicts the hook-end of the grinder. This enables a three-point contact to be made on the journal by means of roller bearings. The hook is held in position on the journal by means of a spring. Provision is made by means of two tracer arms on the hinge frame to centre the hook on the journal and then lock it in position. The actual cut of the grinding wheel is controlled by means of a large knurled wheel at the foot of the motor. Provision is made to correct both ovality and taper on the crank-pin. The machine, which weighs only $8\frac{1}{2}$ lb., has a capacity covering crankshafts of 1·6–2·5 in. diameter

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[1] E. P. Barrus, Ltd., London, W.3.

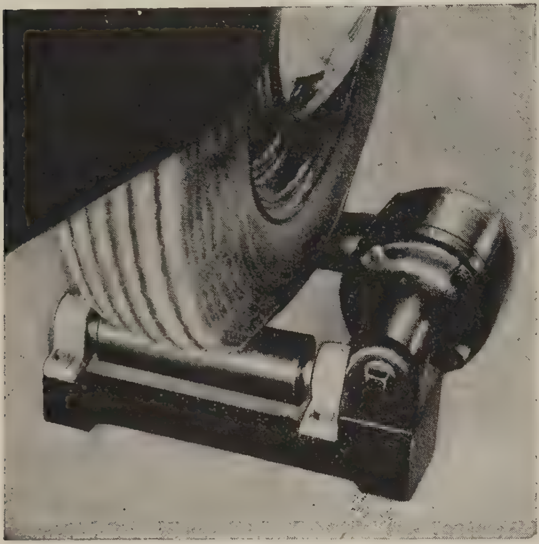

Fig. 403.—The Intheblok Rear-wheel Motoring Unit.

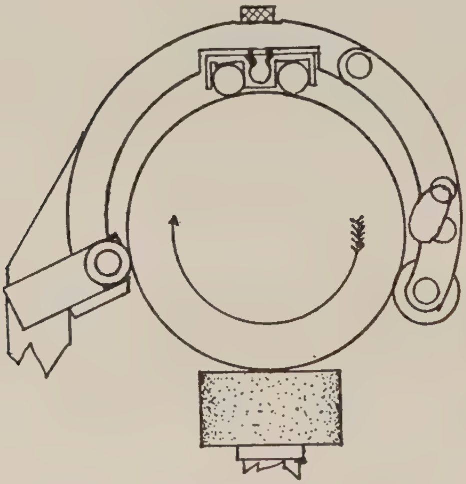

Fig. 404.—Direction of rotation of Crank Journals.

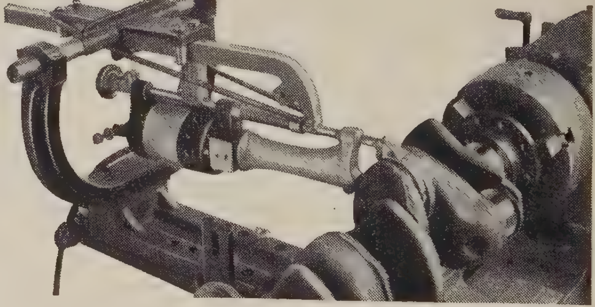

Fig. 405.—The Intheblok Machine used on a Lathe for Crankshaft Main Bearings.

and journal lengths of 1·125–2·75 in.; special equipment is supplied for extending the diameter to be ground up to 3½ in.

Operating Notes for Intheblok Regrinder

When using the Intheblok regrinder, with the crankshaft in position in the engine block on the chassis, it is important to check over the setting up and alignment adjustments before switching on the grinder motor. If the rear road wheel is rotated by a separate electric motor, a convenient single switch of the pedal-operated type can be employed to switch both motors on and off simultaneously. The tension spring holding the hook to the journal should be of sufficient strength to hold the hook firmly but not too tightly—otherwise scoring of the shaft may result.

After setting up, a light roughing or exploring cut should be taken to check whether the stone is cutting parallel.

The subsequent method adopted is to feed the stone into the work with the machine stationary at one end of the journal. After the stone has been fed in 2- or 3-thousandths inch and allowed to grind itself free, the stone should be fed crosswise towards the other end of the journal, letting the leading edge of the wheel make the cut. When finish grinding, however, the stone should be set up so as just to engage the shaft and be swung from side to side continually.

It is important not to attempt too heavy cuts with this machine. Another precaution to be observed is in connection with the top screws on the hook, which must not be adjusted in any way. The roller assembly and motor-shaft bearings should be kept lubricated. The machine gives a kind of wavy surface finish, owing to the edge face grinding action. If the grinding is accurate, as checked with a micrometer, but the finish is not considered entirely suitable, the surface can be given a polish finish using suitable grades of emery cloth, e.g. 150 grit to commence and 320 grit to finish with. The final finish should be obtained using oil on the fine emery surface; care should be exercised in order to apply the emery cloth evenly along the journal.

The Sunnen crankshaft regrinding machine employs a small grinding wheel which cuts on its end face, there being, however, a central hole in the wheel. The wheel traverses or crosses the face of the journal as the latter is slowly rotated. In effect, this machine operates as a centreless grinder and corrects for both ovality and taper effect.

The Intermediate-type Regrinder

To this class belong machines such as the Prince, Lemco, and Seest, that are used in motor-engineering reconditioning shops, where the installation of more elaborate machines would not be justified by the amount or range of work. These machines, however, are capable of a good output of ground journals at an average speed per grind that compares favourably with that of larger machines.

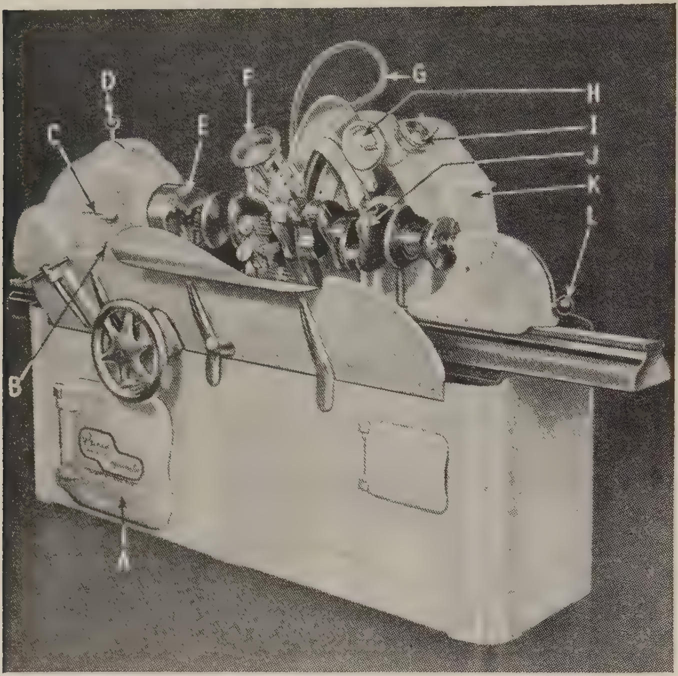

Fig. 406.—The Prince Crankshaft Regrinding Machine.

A—Suds Tank Door. B—Stationary Centre Block. C—Variable-speed Control Knob. D—Control Lever. E—Crankshaft Chuck. F—Finger-gear Unit. G—Coolant Hose. H—Rapid Control Wheel. I—Micro-feed Wheel. J—Crankshaft. K—Wheelhead Drive Casing. L—Tailstock Locking Lever.

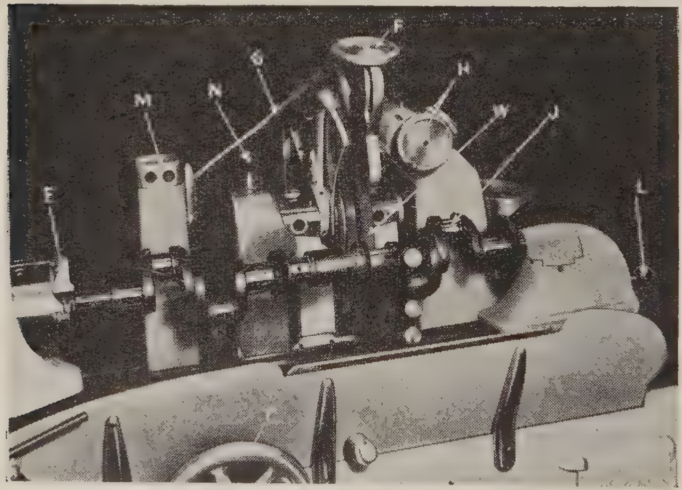

Fig. 407.—Closer View of Prince Machine.

C—Traverse Wheel. E—Crankshaft Chuck. F—Finger-gear Unit. G—Coolant Hose. H—Rapid Control Wheel. J—Crankshaft. L—Tailstock Locking Lever. M—Motor Controls. N—Manual Control of Rocking Frame. W—Grinding Wheel.

The Prince[1] regrinder, illustrated in Fig. 406, is based upon the principle of the "centreless" grinding machine for the crank-pins and the ordinary or plain cylindrical grinder for the main journals. The latter are ground between centres, using a fixed feed for the grinding cut.

For the crank-pins, the grinding wheel is related to the work to be ground by special "fingers" instead of the usual centreless-grinding-machine method that uses a control wheel. The arrangement used in the Prince machine allows the crankshaft to be mounted for grinding all journals between a driving chuck and an ordinary spring tailstock, the grinding wheel being mounted so that it can follow the eccentric movement of the offset journals. The grinding wheel is mounted on a rocking frame, swinging on hardened knife edges. The fingers which are shown in Fig. 407 are used only when grinding crank-pins. They control the relation of the grinding wheel to the journal in

[1] Prince (Kingston) Engineers, Ltd., Kingston, Surrey.

such a way that the largest possible diameter of shaft is retained in service. Another advantage is that by means of the fingers a shaft, the journals of which are already round, can, in a very short time, have as little as ·0005 in. removed from the diameter dimension. The fingers are mounted on an arm having hubs which run direct on the nitrided steel spindle, so that the arm, regardless of wear, moves in an exact radius about the wheel spindle axis. The rocking frame is weighted in such a manner that it is biased away from the machine operator and maintains as nearly as possible a constant tension in the "finger-arm."

The process adopted for grinding the crankpin journals is somewhat unconventional, the crankshaft being rotated at the low speed of 5–6 r.p.m. for the roughing operation, and less than 2 r.p.m. for the finishing process. The in-feed when roughing is, however, still quite high, namely, about ·0015 in. per revolution, and the finishing operation only takes place for the last turn or two of the crankshaft.

A stepless variable-speed workhead is provided; this gives speed ranges of 1½–10 r.p.m. for the crankpin journals and 20–60 r.p.m. for the main journals.

The principle employed is such that it is not possible to put the usual pressure behind the grinding wheel, so that it is important to balance the wheel accurately. Even so, a fine, close-pitched shimmer appears on the journals after grinding, although this cannot be measured when a ·0001-in. dial gauge is employed, for it is the practice to polish the ground journal using fine emery—an operation occupying only about two minutes. No allowance need be made on the journal for this purpose, and the resulting surface represents a high standard of finish and dimensional accuracy.

One advantage of the principles employed in the design of this machine is that the initial set-up time is very short, seldom exceeding from three to five minutes. After grinding the main journals, the change over to the commencement of grinding the crankpin journals takes about thirty seconds.

A special feature of the Prince machine is the provision of three adjustable balance weights in the grinding-wheel hub, for *balancing the grinding wheel*. A vibrating-reed pattern vibrometer is fitted for checking the balance to very fine limits.

The machine has a capacity for crankshafts up to a maximum length of 45 in. and crank throw of 3 in. The maximum crankpin journal catered for is 2·9 in. diameter, and main journals up to 3·5 in. The maximum diameter that can be accommodated in the chuck jaws is 6·5 in.

Larger Grinding Machines

The Van Norman[1] crankshaft grinding machine, shown in Fig. 408, belongs to the larger class of machine used for regrinding crankshafts in automobile engine servicing, since it will deal with shafts up to 48 in.

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[1] E. P. Barrus, Ltd., Acton, London, W.3

long, in the case of No. 448 model. It has been designed for general ease of operation and quick results in the hands of the trained operator.

The workhead has a dry-type multiple disc clutch to facilitate the rapid setting up of the work; a lever is provided for operating the clutch. The chuck or faceplate of the workhead is graduated in degrees, up to 360°, to enable quick setting of the shaft for crankpin grinding. The tailstock spindle has a travel of 3 in. for work-setting purposes. Both the headstock and tailstock are provided with rack-and-pinion travel. The grinding head has a self-contained wheel-spindle unit with ball bearings for taking the thrust and roller bearings for the load. The grinding wheel is of 28 in. diameter and is driven by its own electric motor. The workhead can be driven at three speeds, namely 30, 60, and 100 r.p.m. The grinding-wheel unit is provided with a rapid approach and recede movement, which saves much time when the work has been set up and grinding is to begin. It requires only one revolution of the control wheel to bring the grinding wheel to within a few thousandths of an inch of the work. A positive stop is provided for the advance position of the grinding wheel; a micrometer device then comes into use for precision depth adjustment.

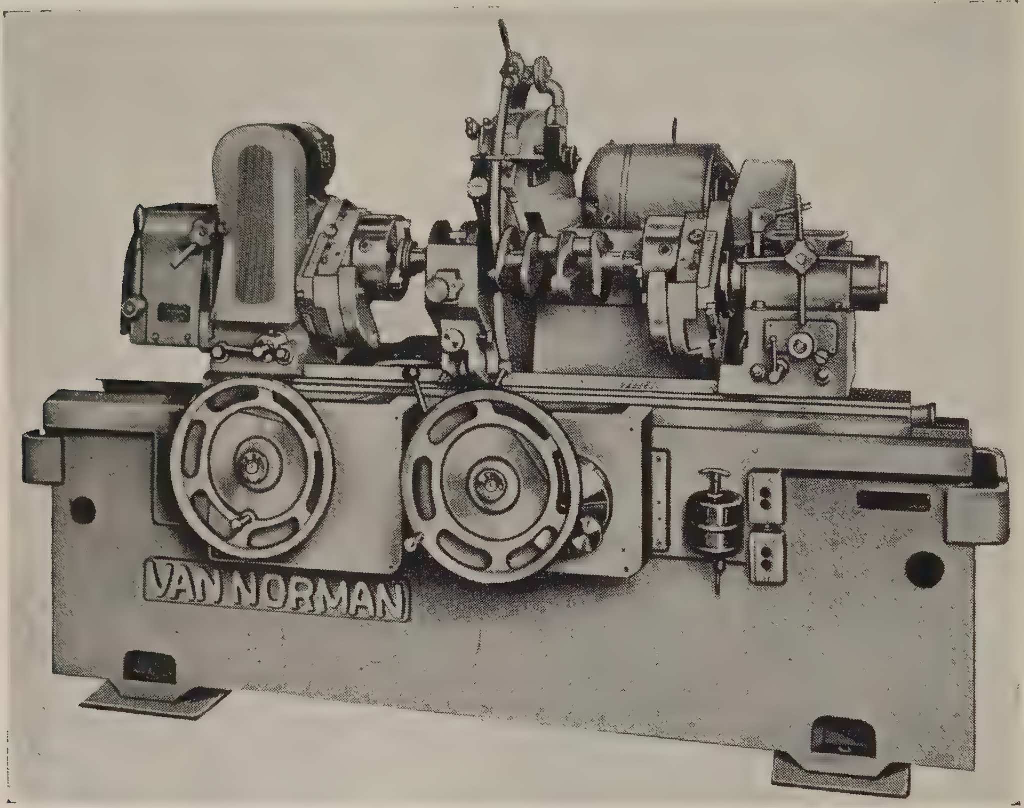


Fig. 408.—The Van Norman Crankshaft-grinding Machine.

The grinding operation is done wet, a coolant being pumped continuously from a large reservoir in the base of the machine by a $\frac{1}{2}$-h.p. electric-motor-driven pump. The machine is supplied with a set of balance weights so that each crankshaft can be accurately balanced in order to avoid vibrational effects that would affect the grinding precision and finish.

The Churchill crankshaft grinding machine shown in Figs. 409 and 410 is a high-precision machine made by a firm of grinding-machinery specialists, and it has every refinement for convenience of setting, grinding, and high finish, whilst covering a wide range of crankshaft sizes from those of small cars to large commercial-vehicle Diesel engines. It has quickly adjustable throw blocks for setting the crank-pins to the correct throw for regrinding; live workhead and tailstock for crank-pins and dead centres for the main journals; an electric indicator *for balancing the crankshaft*; special Hydrauto grinding-wheel spindle-bearing adjustment and a Nitralloy steel grinding-wheel spindle; separate drive to the work by belt, no gears being used; a patent swarf separator which ensures a high degree of finish on the work, longer grinding-wheel life and consequent less wear on the diamond tool which is used for truing the tool. Finger-tip control is employed for the control of the table traverse. Hydraulic feed for this table is provided, as distinct from the usual lead-screw and nut method used on lathes.

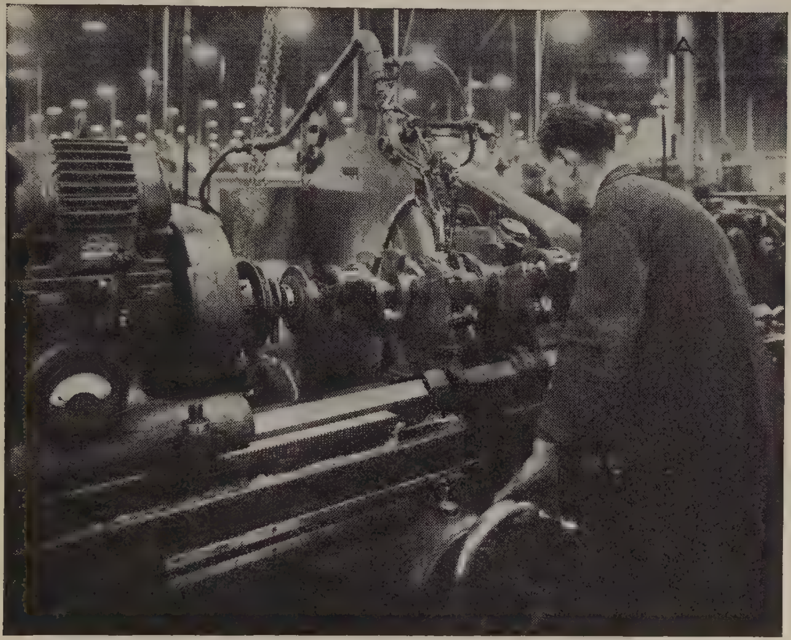


Fig. 409.—The Churchill Crankshaft-grinding Machine.

Fig. 411 illustrates the throw blocks used when regrinding crank-pins, self-centring chucks being employed to grip the end main journals; a screw adjustment is used to regulate the offset or crank-pin "throw." As an alternative the throw blocks can be supplied with bearing mountings.

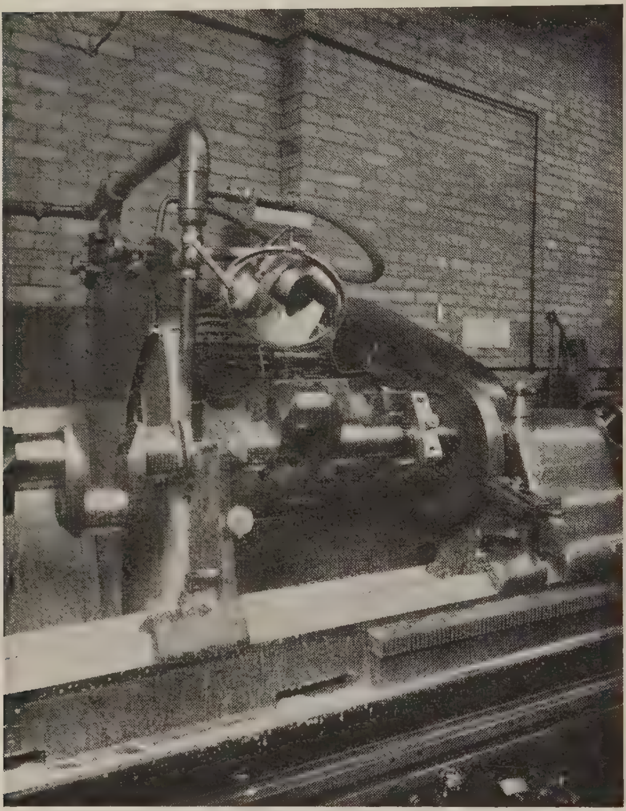


Fig. 410.—Close-up View of Churchill Crankshaft-grinding Machine, showing Steady and Mirror for Work Inspection, etc.

Accurate setting of the crank-pin throw is ensured with the aid of V-gauges provided for the purpose. Two steadies are employed for journal regrinding.

The hydraulic mechanism operating on the longer machines through the Churchill speed multiplier gives a continuously variable range of table traverse speeds up to 144 in. per min. with shockless reversal at all speeds. The length of the stroke is accurately set by trip dogs having fine adjustment for grinding up to shoulders.

The grinding-wheel head is arranged with hand and variable automatic feed to give a reduction measured on the diameter of the work of from ·00025 in. to ·001 in.

In regard to the grinding swarf separator, the flow of coolant from the machine is discharged tangentially into a circular tank, thus centrifuging the solid matter in the coolant on to the outer perimeter of the tank from which it can be readily removed. The cleaned coolant is taken from the centre of the tank.

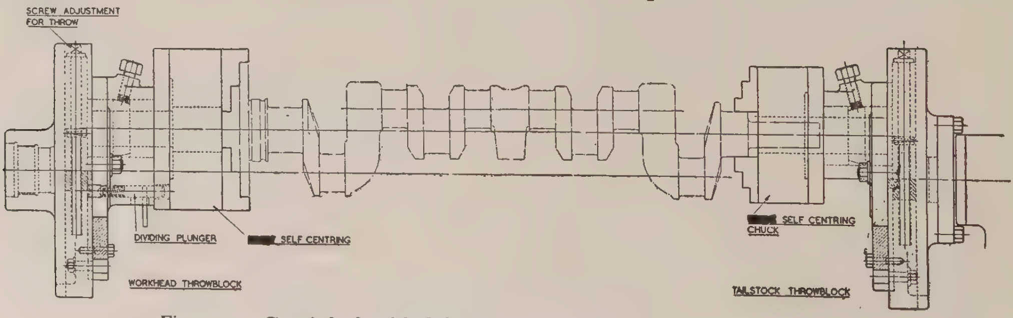


Fig. 411.—Crankshaft with Self-centring End Chucks and Throw Blocks.

The Churchill machines are made in four models, each of 20-in. maximum swing over the table and with grinding lengths between the centres of 36, 50, 72, and 84 in. respectively.

Mention should be made of a large circular-disc adjustable type of mirror which is fitted to these machines to enable the position of the work in relation to that of the grinding wheel to be visible at all times to the operator. It also allows the latter to use the wheelhead quick-hand movement with safety.

The machines are provided with fixtures for holding pistons that are to be ground, as shown in Fig. 412.

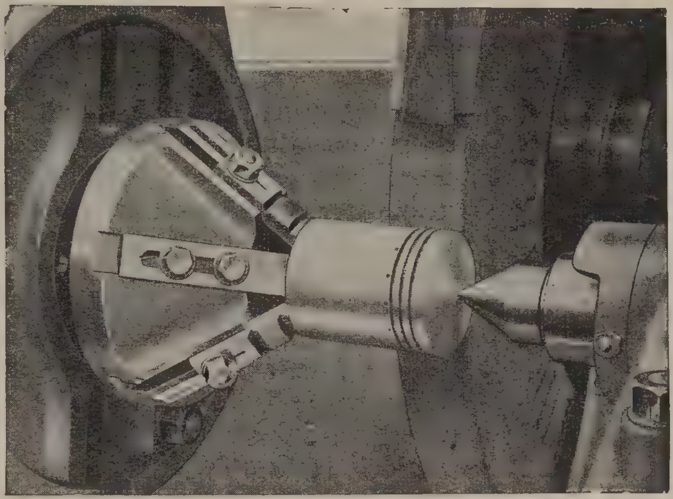


Fig. 412.—Showing how Pistons are held and ground on the Churchill Machine.

Practical Grinding Notes

Choice of Grinding Wheels.—Whilst the manufacturers of grinding machines invariably fit the best type of abrasive wheel for regrinding purposes, it is as well to note the correct grades for general rough and also finish grinding purposes.

The recommended types of grinding wheels for crankshaft regrinding are of the aluminium-oxide (Aloxite) vitrified type, with grits of about 40. A particularly good abrasive wheel is the Carborundum Aloxite vitrified 40C Grit, Grade I and Bond BLU/DG.

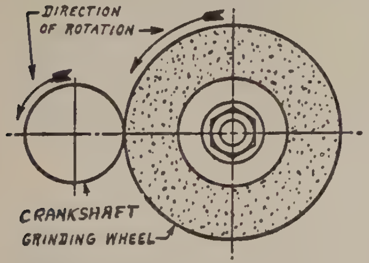


Fig. 413.—Directions of Rotation of Work and Grinding Wheel.

Speeds.—The grinding wheel should run at a surface speed of 5,500–6,500 ft. per second, so that a wheel of 1 ft. diameter should rotate at about 1,750–2,070 r.p.m. The crankshaft journal should run at about 60 ft. per minute, so that a journal of 3 in. diameter would be rotated at about 80 r.p.m.

Directions of Rotation.—The correct directions of rotation of the work (crankshaft journal) and grinding wheel are as shown in Fig. 413. At the point of contact the wheel and work are moving in opposite directions, so that the directions of rotation of both parts are the same.

Wheel Width.—In most crankshaft regrinding machines the wheel is of sufficient width to need no traverse movement, so that a full-width cut will clean up the journal. The wheel is radiused to suit the fillets of the journal. Usually the main journals are ground first and the crankpins second.

Cutting Procedure.—It is important to make the first grinding cut a trial one, and then, if everything is satisfactory, to proceed with a truing cut, taking off the bare minimum to bring the journal to the available first undersize bearings. In some cases the journal is left two or three thousandths high, and is fine-hone or lap finished to size, in order to give a good polish finish.

Balancing.—The crankshaft, as explained earlier, should be properly balanced before the journals are reground; most machines make provision for such balancing. The grinding wheel must also be balanced, and this operation should be done with precision, on account of the relatively high speed at which the wheel runs. Small out-of-balance effects may cause serious wheel vibrations which will affect the accuracy and finish of the work.

Truing.—The wheel should be dressed after so many crankshafts have been ground, using a diamond tool and running the wheel at its normal working speed. Steadies should always be used, and as close as possible to the journal being reground.

Finishing by Rolling.—It is now becoming the practice, in the case of the highest-grade cars, for manufacturers to finish their crankshaft journals (both pin and main ones) with a roller, which is simply pressed against the rotating shaft and allowed to rotate freely under this action. The rolling action causes the surface to flow slightly so as to fill up the microscopic pits, and to polish the surface very satisfactorily.

Fig. 453, page 375, illustrates a finishing roller described in *The American Machinist*, and is stated to give an excellent finish. The roller was mounted on a journal ball bearing, a thrust washer being provided on one side.

In using this tool it was found, after much experimenting, that a far better finish was obtained if the work was coated with black oil than with any other lubricant.

While the rolling operation requires a fairly high pressure, it was found that the ball bearings did not require adjustment more frequently than about once every year; the average number of shafts rolled each day was thirty.

Holding Crankshafts in the Lathe

The ordinary petrol-engine crankshaft is not an easy thing to handle in the lathe for the purpose of turning or grinding the journals. As regards the main journals, however, there is no difficulty once the shaft is centred—usually the original centres will be found to have been left in; this greatly facilitates setting up.

When centred, the ordinary four-cylinder vertical type of the two-bearing pattern will be found short, or stiff, enough to operate upon directly. In the case of three-bearing crankshafts, however, it is advisable to fit a steady rest on the centre bearing when working on all three main bearings, in order to prevent springing or chattering; the slightest vibrational effect will reduce both the accuracy and the quality of the finish.

When the crank-pins have to be trued in the lathe by any of the methods previously described, it is necessary to swing the shaft so that it rotates about the axis of the pin to be operated upon. The usual amount of crank-pin radius or throw is about $1\frac{1}{2}$ to 3 in., according to the size of engine, so that provision must be made for holding the shaft this amount out of centre relatively to its main axis. Since there is not enough distance in the diameter of the crank main journal to offset the centres in the shaft itself by this amount, it is necessary to use a special centre-plate jig attached to the crankshaft. This is simply a stout metal plate—in steel or cast iron—fitted to the crankshaft end, and long enough to take the centre for the poppet.

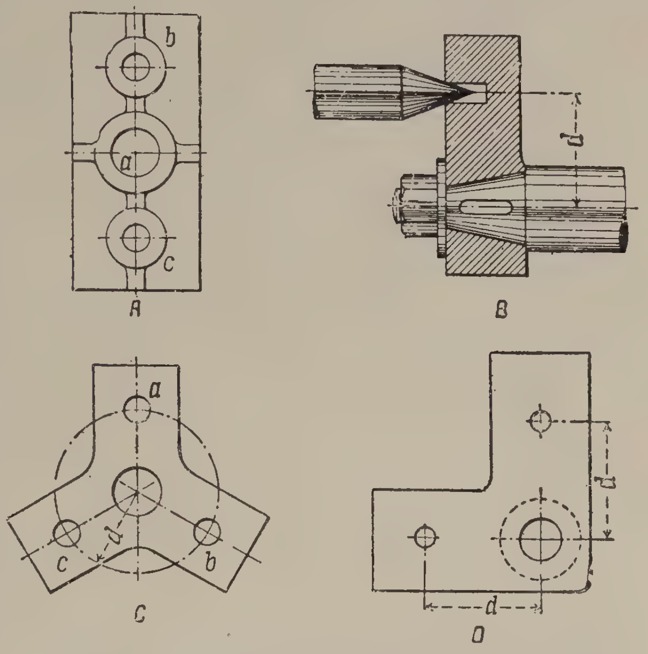


Fig. 414.—Lathe Centre Jigs used for turning Crankshafts.

Fig. 414 illustrates various types of crankshaft centre plates or jigs which are used for this purpose. Fig. 414 (A) shows the centre jig for a two or four crankshaft, with cranks all in line as in the case of the two-cylinder opposite and four-cylinder vertical engine types; the eight-cylinder in-line crankshaft is sometimes made with all cranks in the same plane. The plate is simply bored taper to fit the cone end of the crankshaft, and preferably keywayed to suit the key on the shaft. The centre on the plate should be accurately marked off on the marking-off table and carefully drilled and countersunk. The distance *d* between the centres and the main crank centre (Fig. 414 (B)) is equal to the crank-throw, that is, to one-half the piston stroke.

Fig. 414 (C) shows the form of centre jig used in the case of a six-cylinder vertical engine.

Fig. 414 (D) is another type of centre jig used for a crankshaft having its cranks at right angles (instead of 180°) to one another.

It is quite a straightforward matter to provide one of a pair of centre jigs with a projection for engaging with the ordinary lathe face-plate driving stud or bolt, as shown in Fig. 415; this illustration depicts a four-cylinder crankshaft set up in the lathe. At one end, namely the driving-plate one, there is a special plate bolted to the circular flange piece on the crankshaft.

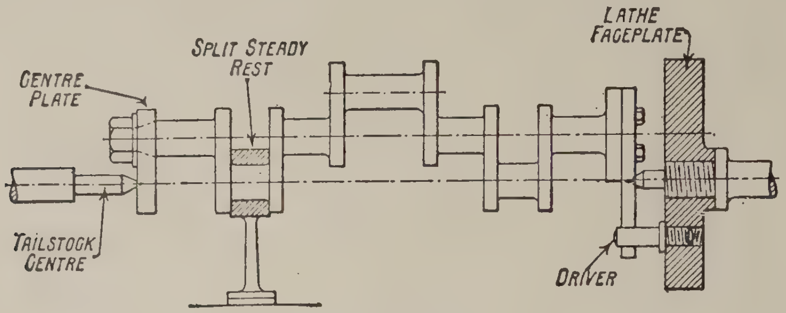


Fig. 415.—Illustrating Method of Setting-up Crankshaft in Lathe.

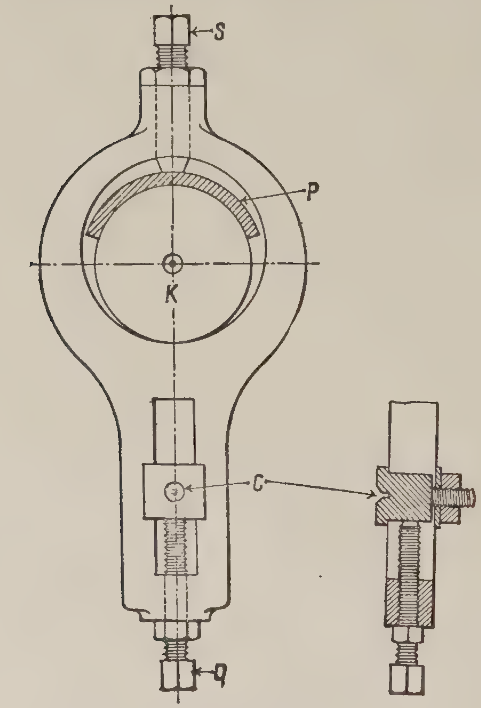
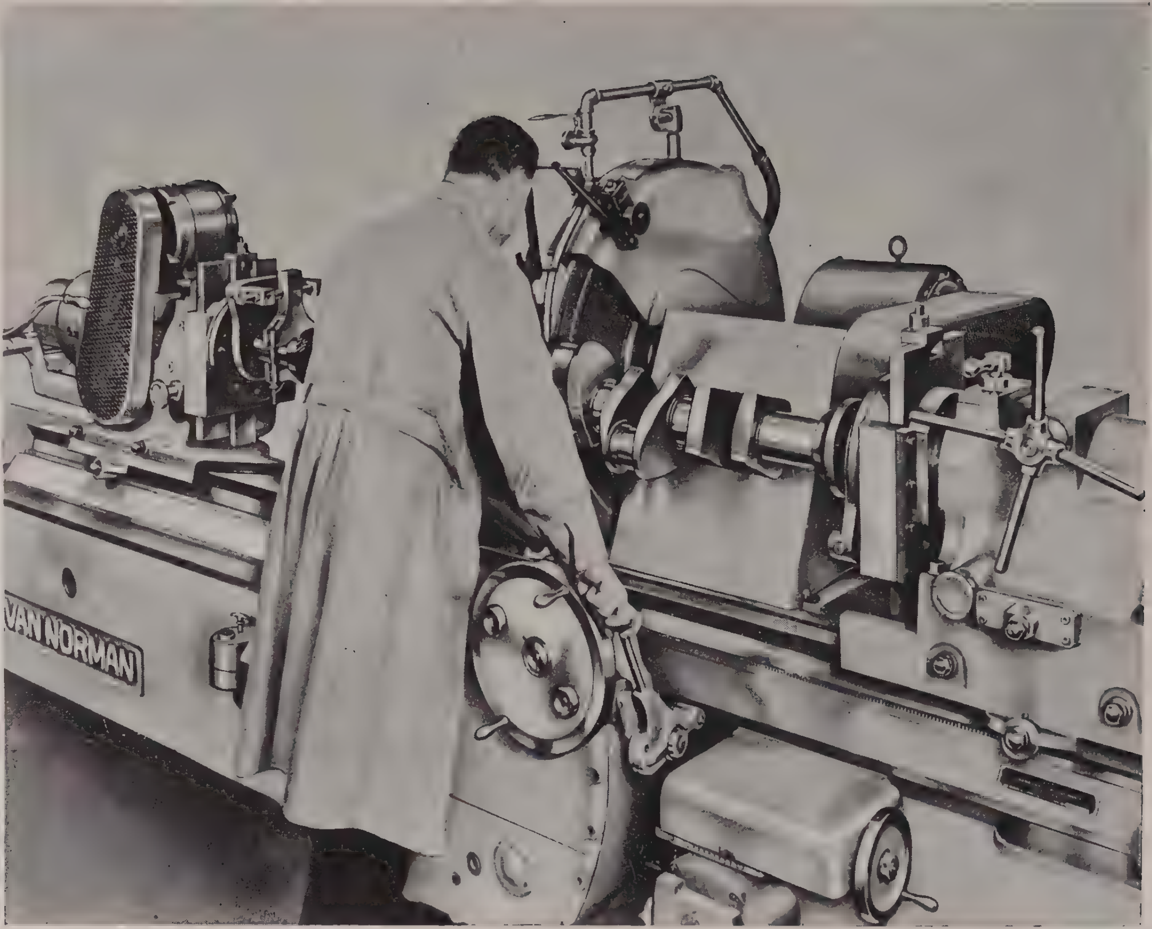


Fig. 416.—Universal Lathe Centre for Crank-pin Operations.

The use of an *adjustable centre* will itself be found of much service in workshops where different sizes and types of four-cylinder crankshafts have to be dealt with. In this pattern of centre plate (Fig. 416) a hole which is rather larger than the outside diameter of the crankshaft K is provided, and set-screw S clamps the packing piece P against the shaft, so as not to injure the latter. The sliding centre block C can be rigidly clamped in any position, once it has been accurately adjusted by means of the set-screw Q. With this device the crankshaft can be accurately aligned by the trial-and-error method. It is necessary to set the radius KC a little greater than the crank-throw, and then to adjust, gradually, the screw Q until the crank-pin rotates concentrically with the lathe centres; the centre-piece C is then securely clamped by means of the screw and nut provided for this purpose.

An improvement on this design would be to have a fine-threaded continuous screw engaging with a thread tapped or cut in the centre-piece C; it would, however, still be necessary to clamp C to its slide once it had been adjusted to the proper position.



GRINDING AN OIL-ENGINE CRANKSHAFT, 69 IN. LONG, WEIGHING 500 LB., IN A VAN NORMAN NO. 111. CRANKSHAFT-REGRINDING LATHE.

Preventing Vibrations or Chatter

When grinding or turning the crank-pins or journals of long crankshafts there is a tendency for the lathe tool to chatter owing to the spring of the crank webs. This can be prevented by placing bolts and nuts between the webs of the crank members which are not actually being ground or turned (Fig. 417). Alternatively, blocks of hard wood can be used, as shown in Fig. 418.

In some cases it will be found convenient to employ a lathe steady (or steadies) on the adjacent crank-pins or journals, as the case may be.

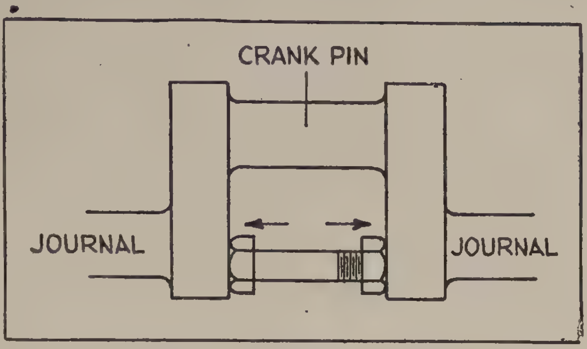


Fig. 417.—Method of preventing Chattering or Vibration.

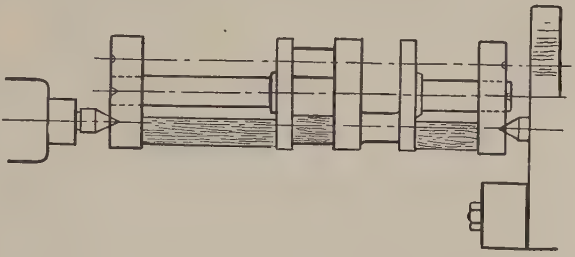


Fig. 418.—Wooden Struts for preventing Vibration during Grinding.

Chromium-plated Crankshafts

The lives of the journals and main bearings of a crankshaft may be extended considerably, before they require to be trued again, if these surfaces are chromium plated. Although the process in question adds to the cost of the crankshaft, the extremely hard polished surface obtained practically dispenses with the necessity for reconditioning the cylindrical surfaces during the whole life of an engine. One or two manufacturers of the more expensive types of British car employ chromium-plated crankshafts, whilst many racing-car engines are fitted with them. The subject of chromium-plated crankshafts and other parts is dealt with more fully in Volume III.

When reconditioning engines that are to be subjected to further long periods of work, the question of chromium-plating the crankshafts and camshafts is worthy of consideration. The process is not an unduly expensive one and can be undertaken by firms such as Messrs. Fescol, Ltd.

Metal-spraying Process

Worn crankshaft journals may also be built up by *spraying molten metal* upon the worn surfaces. The British Oxygen Company's process of spraying high-carbon steel utilises the oxy-acetylene flame for melting the steel rod, the molten metal being forced by a high-pressure blast on to the crankshaft journal or pin. It is necessary to knurl or finely screw-thread the journal beforehand to obtain a satisfactory bond with the sprayed metal. The steel thus sprayed in firmly interlocks with the surface metal of the crankshaft, so that, to all intents and purposes, it is integral with the latter. After spraying, the enlarged journals or pins are ground to size.

In the Metalisation spraying process, by which alloy steel, nickel or chromium is sprayed on to the previously roughened journal any desired thickness of deposit can be built up. To obviate reducing the diameter of the worn journal by knurling or cutting a fine-pitch screw thread, a recent method utilises a special welding device to deposit a rough surface deposit of metal on to the journal; this affords a fully satisfactory " key " for the sprayed metal.

Welding Repairs to Crankshafts

A few years ago most motor engineers would have scoffed at the suggestion of repairing a fractured crankshaft by welding, but to-day this work is, to our personal knowledge, being carried out with every satisfaction, and at an appreciably lower cost than that of a new crankshaft. The earlier difficulties of welding alloy-steel shafts, and of ensuring a welded joint of at least equal strength to the original metal, appear to have been overcome, for there are numerous examples of welded crankshafts having been in service for years.

When a crankshaft breaks it is usually at the junction of one of the journals with a crank-web, and there is invariably a certain amount of distortion due to the fracturing process; so that not only must the broken parts be welded together, but the shaft must be made quite true again.

It is usual to employ the electric arc welding process for this work; the crankshaft to be repaired being blocked up on a metal table with metal blocks, so that the table forms one electrode, as it were, of the electric circuit. The broken parts are packed up in this way and aligned as accurately as possible by eye, and are then tacked in places with the electric arc, so as to obtain a temporary attachment. The " tacked " crankshaft is then taken to a lathe and trued up by judicious tapping, until it is passed as suitable for final welding. The latter process is done by cutting, with the arc, V depressions along the contour of the fracture, and filling in with a special alloy feeder rod. Wherever possible a surplus of metal is left, so as to still further strengthen the weld.

Messrs. Barimar state that the cause of broken crankshafts should be ascertained, since new or repaired shafts may break down again; such breakages may be due to worn bearings or to bearings out of true.

It is impossible when repairing crankshafts by welding to obtain the same forged-steel grain or crystal structure as in the original crankshaft; this accounts for the slight loss of strength of welded crankshafts. The factor of safety is usually sufficiently high to take account of the slight loss of strength in question. Repaired crankshafts are, of course, machined and ground to accurate limits; in high-class repair work they are also rebalanced.

If a crankshaft belonging to an engine which has been in heavy service for several years fractures, it is probably due to the accumulative effect of gradual fatigue of the metal under the repetition of bending and torsional stresses, so that the whole of the crankshaft metal will have become altered in crystalline structure—a condition which cannot be remedied, except by annealing and rehardening. In such cases it is always advisable to obtain a new crankshaft, rather than repair the old one, since it may fracture again in a fresh place.

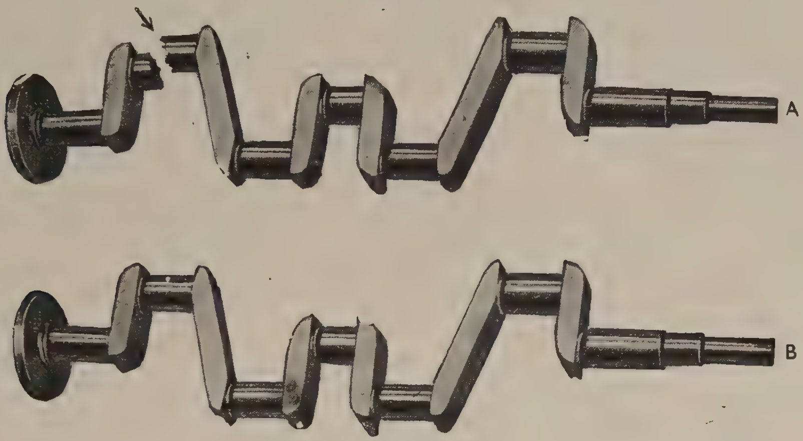


Fig. 419.—(A) Showing Fractured Crankshaft. (B) The same Shaft repaired by Arc Welding Process (Barimar).

Balancing of Crankshafts

Although to balance a crankshaft accurately for both static and dynamic conditions requires the use of a special crankshaft balancing machine, such as the Olsen, Carwen, or Avery types, it is possible to balance a crankshaft statically by means of the simple apparatus shown in Fig. 420.

This apparatus consists of a pair of angle-irons having their upper edges perfectly flat and finished to practically a knife-edge. They must be mounted on a rigid bench so as to be absolutely horizontal and also parallel one to the other.

The crankshaft to be tested is placed on the knife-edges as shown, when, if it is out of balance, it will always roll along the knife-edges so as to rest in the same position. By judicious drilling—so as not to reduce the strength of the crankshaft—or by drilling or adjusting the counter-balance weights (when fitted), the shaft can be balanced so that it will rest on the knife-edges in any position.

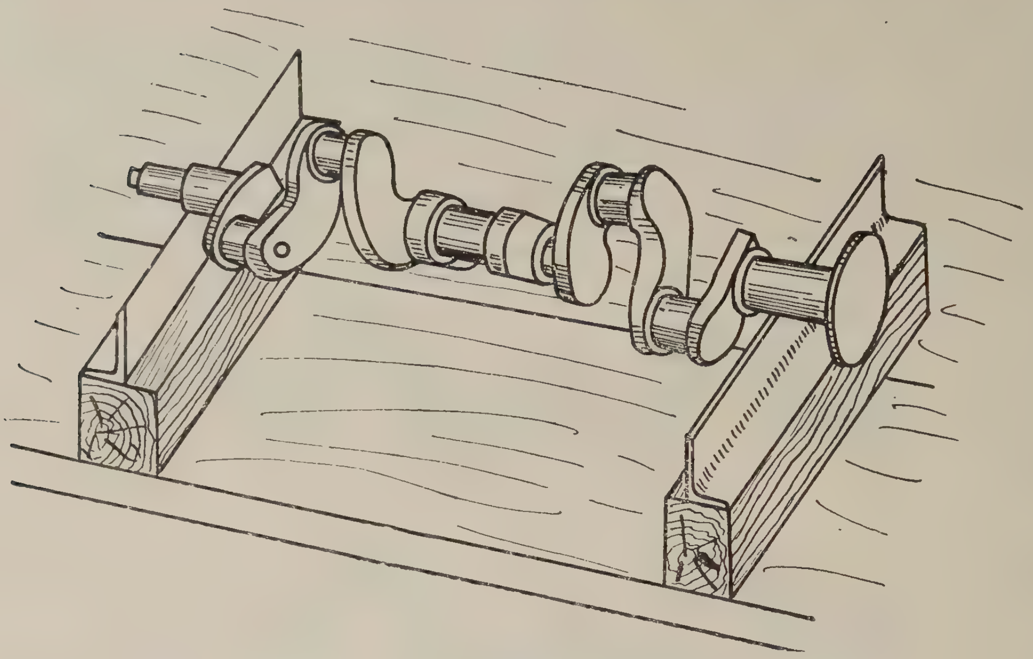


Fig. 420.—Illustrating one Method of testing a Crankshaft for Static Balance, by rolling the Shaft along a Pair of Knife-edges. If in proper balance it should come to rest in any position.

The method of balancing crankshafts by means of the Avery crankshaft machine is shown in the right-hand illustration of Fig. 421. An electric motor is used to drive a countershaft, from which a belt drive is taken to one of the crankshaft main journals; the crankshaft is mounted on friction

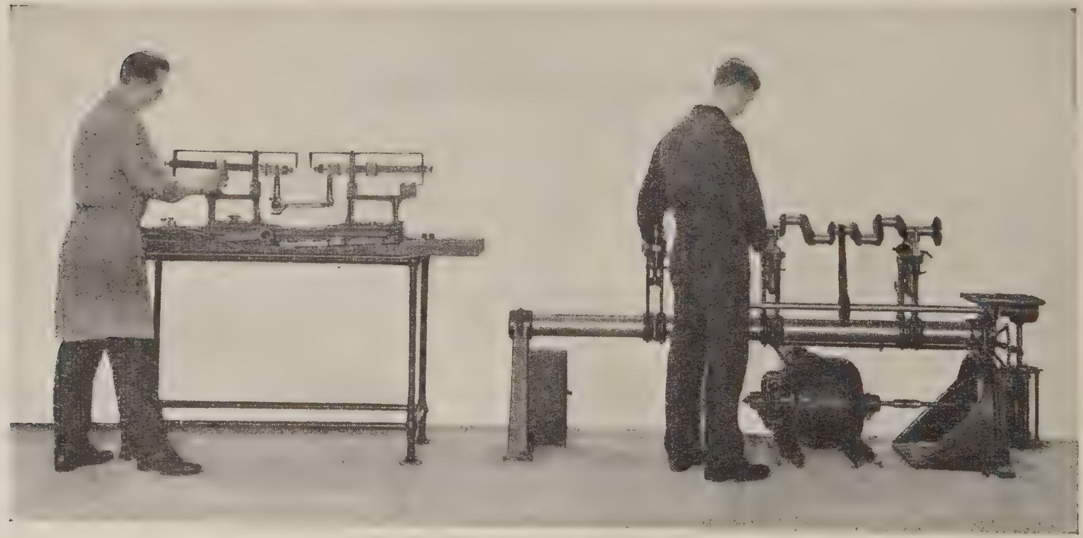


Fig. 421.—The Avery Connecting-rod and Crankshaft Balancing Machines.

wheels at its two ends. Any out-of-balance effects are shown by the vibration of the crankshaft as it is rotated at high speeds. The left-hand illustration shows how connecting rods are checked, not only for total weight, but also for the weights of the two sections, to ensure that the centre of gravity is in the same position for a given set of connecting rods; this is necessary to ensure correct balance of the rods in multi-cylinder engines.

The Flywheel

After an engine has seen long service and the crankshaft has been taken down for regrinding, the flywheel, with its starter ring, should be inspected for the following possible faults:

(1) Elongated holes in the part that is attached to the crankshaft flange.
(2) Damaged starter teeth.
(3) Scored clutch engagement face.
(4) Embedded material in the crankshaft palm due to " fidgeting."

Elongated holes are caused by the flange attachment bolts having become loose. In such cases, although it is quite feasible to reamer out the holes in the flywheel and flange and to fit oversize bolts, it is sometimes advisable to fit a new flywheel. If, however, the crankshaft flange holes are also elongated, the reaming method should be employed.

A frequent fault is that of *starter-ring teeth becoming severely damaged* by the starting-motor pinion. This damage will be found to occur in certain places on the starter ring only, and it is possible to remove the ring and turn it round to a fresh position on the flywheel, so as to bring into action undamaged teeth.

In the case of a six-cylinder engine there are three places equally spaced around the starter ring at which tooth wear occurs. If the teeth are *chamfered on one side* only, then it is possible to move the ring to only one other position on the flywheel. If the ring has teeth *chamfered on both sides*, then, after moving it to the intermediate position, should the teeth become worn again the ring can be reversed and *two further positions* obtained, making three in all.

Removing Starter Ring

The procedure for removing the starter ring, which is made a shrink fit on the flywheel, is best described by taking the case of an actual engine, namely the Bedford 28-h.p. six-cylinder one. The method recommended is as follows:

(*a*) If the ring is to be repositioned, mark the position of the worn teeth clearly on the flywheel.

(*b*) Hold the flywheel assembly firmly in a vice with suitable wood packings between the vice jaws and the flywheel web, making sure that the ring gear is clear of the vice and that the packing pieces will allow the ring to be driven off the flywheel without fouling.

(*c*) Using a hammer and a piece of wood as a punch, drive the ring gear evenly from the flywheel, striking alternately at three points equally spaced round the circumference. Make sure that the teeth are not damaged in the process.

(*d*) Remove the flywheel from the vice and lay it on the bench with the register for the ring gear uppermost.

(*e*) Polish three evenly spaced places on the outer side of the gear with emery cloth.

[*Important.*—If the gear is to be repositioned, polish the three places midway between the worn sections of the teeth.]

(*f*) The next operation is to shrink the ring on to the flywheel. Heat the gear in a furnace or oven. If this equipment is not available, place the ring gear on a suitable iron plate and heat it evenly. The temperature of the gear can be judged by the changing colour of the polished sections on the face of the gear. The correct temperature is reached when the colour has changed from *purple* to *dark blue*. Hold at this temperature for five minutes.

[*Special Note.*—Do not allow the temperature to exceed 320° C. (608° F.), *dark blue* colour. If the colour changes to *light blue*, the original heat treatment given to the gear during manufacture will be destroyed.]

(*g*) Remove the scale from the face of the gear and drop it rapidly in position on the flywheel. If the gear is to be repositioned, locate it so that the three polished sections on the gear are in line with the markings made on the rim of the flywheel. If necessary, gently tap the gear home with a copper hammer.

(*h*) Allow to cool in air.

A new ring gear is fitted in exactly the same manner.

In the case of the Morris commercial engines, the starter ring has three equally spaced grub screws which must be removed before the ring can be taken off. When the ring is repositioned it is necessary to drill and tap three fresh holes for these grub screws; the latter are $\frac{5}{16}$-in. diameter B.S.F. by $\frac{7}{16}$ in. long.

Quick Removal Method for Worn Starter Ring

When the starter ring is worn so much that it is to be replaced by a new one, the old ring can be removed very easily by a method that is advocated by Morris Commercial Motors, Ltd., as follows:

Drill one $\frac{1}{4}$-in. diameter hole through the starter ring between a pair of teeth, and, after inserting a suitable tapered end, punch drive the latter into the hole to burst the ring, when the latter can be knocked off the flywheel with a hammer.

Checking Accuracy of Flywheel

When refitting the flywheel it is first important to make sure that it is placed on the crankshaft flanged member in the same position as before removal. Unless this is done the T.D.C. mark on the flywheel rim will be in the wrong position, and this will occasion much trouble when timing the ignition or valves.

The joint faces should be perfectly clean before reassembly, and the nuts on the flange bolts tightened in diagonal order. After the nuts have been tightened up the clutch face of the flywheel should be checked for accurate running with the aid of a dial gauge in the manner illustrated in Fig. 422. The gauge is mounted on the crankcase as shown, and its plunger brought into contact with the face of the flywheel, reading being noted. The crankshaft is then rotated slowly by hand and the readings of the gauge observed. If the maximum difference between the readings does not exceed ·003 in. for a complete revolution, the flywheel face may be considered satisfactory. Otherwise it will be necessary to grind or machine the face so that it is accurate. It may be added that certain clutch troubles are attributed to inaccuracy of the flywheel, so that the test recommended is an important one.

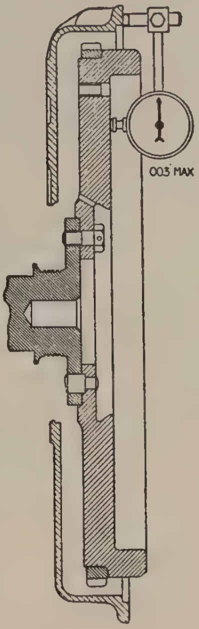


Fig. 422.—Checking Accuracy of Flywheel (Morris Commercial).

The Crankshaft Oil Seals

Since the crankshaft passes through the crankcase at the forward end where the belt pulley is fixed and at the rear end into the clutch casing, it is necessary to ensure that no lubricating oil can escape at either end. In this connection it must be remembered that the oil is supplied under a pressure of 30–60 lb. per sq. in. to the main bearings, and that the rear bearing is very close to the exit aperture of the crankshaft. The escape of oil is more difficult to prevent at the rear end on this account. The usual method (Fig. 423) is to provide a sharp edge ring on the shaft just beyond the back face of the rear bearing, and to provide an annular chamber all around the oil-thrower ring. The latter throws off any oil that may escape from the rear bearing by centrifugal action, and this oil is caught on the surface of the chamber, draining down to the bottom of same, where it passes down a drilled hole to the oil sump.

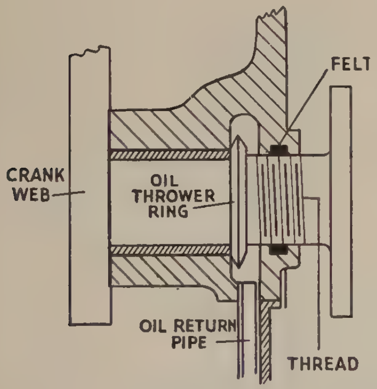


Fig. 423.—Oil-thrower Ring at Rear End of Crankshaft.

Sometimes the portion of the shaft beyond the oil-thrower ring is screw cut, also in such a direction that any oil that may find its way on to the shaft is wound back, as it were, into the oil-catching chamber.

At the front end the crankshaft passes through the timing-gear case, which is oiltight. No attempt is generally made, as a rule, to stop oil leaking from the front bearing into the timing case, but only from the timing cover. Usually, there is an oil-thrower ring which stops practically all of the oil from getting past the timing cover; the oil thus thrown off drains down to the bottom of the timing casing and thence through a hole into the oil sump. It is usual, however, to provide an oil seal in the timing cover. Fig. 424 shows the method used in the M.G. $1\frac{1}{4}$-litre engine, namely by the use of an asbestos sealing ring in conjunction with an oil-thrower ring. The timing chain sprockets are shown on the right of the oil-thrower ring.

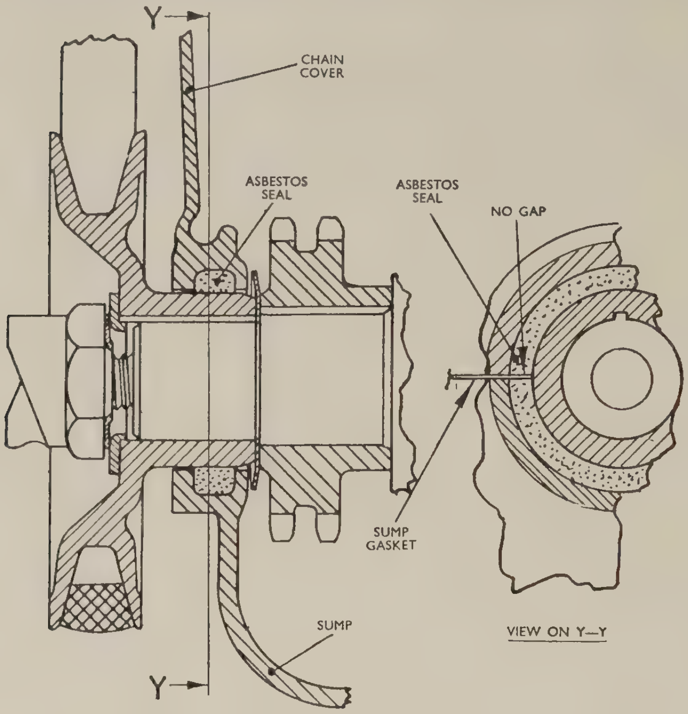


Fig. 424.—Timing Casing Oil Seal (M.G.)

In the Morris Commercial engines a special type of oil seal, known as the Perfect seal, is used in the crankshaft aperture of the timing case. The double-pattern ring is used. Fig. 425 shows the Perfect oil-seal ring, with its metal casing, leather angle-section sealing member, and continuous spiral spring which exerts a light pressure on the leather ring to render the shaft passing through it oiltight.

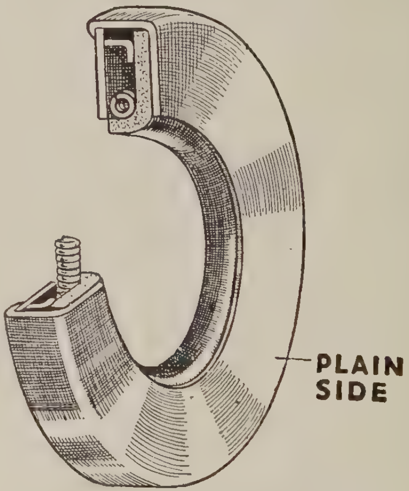


Fig. 425.—The Perfect Oil Seal.

Should the ring become worn or damaged, a new one must be fitted. The oil seals will withdraw with the timing-case cover and crankshaft sleeve. As two Perfect oil seals are used, it is important to arrange the plain faces (see Fig. 425) so that they butt together.

Before refitting, carefully examine the seal, remove all traces of dirt or grit, and clean in light lubricating oil. Finally, wipe with a cloth moistened with clean oil.

Smear the sealing lips with clean grease.

See that the spring is correctly located when in position, and that the seal is squarely and accurately pressed into the housing recess.

Examine shaft, and remove all roughness, sharp edges on keyways, screw threads, splines, and shoulders, over which the sealing lip is passed.

Where necessary wrap a suitable sheet of paper, well greased, round the shaft to cover such sharp edges as might damage the seal as it is inserted. The slightest scratch on the edge can cause leakage.

CHAPTER 12

THE CYLINDERS AND LINERS

Cylinder-truing Operations

The average motor user often has hazy ideas regarding the state of his cylinders, and frequently has no idea when the cylinders should be rebored or reground, but will continue to run his engine in a poor state of efficiency.

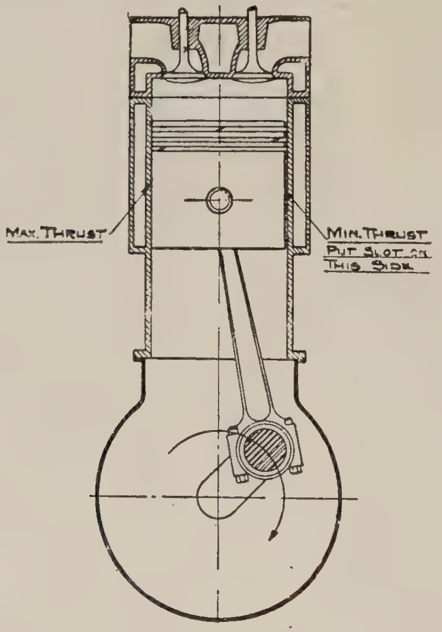


Fig. 426.—This illustration shows the Minimum and Maximum Thrust Faces of the Piston. It also indicates where the Slot of the Slit-skirt type of Piston should be placed.

Although no hard-and-fast rule can be put forward, since every individual case is different, a good deal will depend upon the manner in which the car has been treated. If, for example, the engine has been driven at excessive speeds when new, has been starved of oil on occasions, or has been run in a badly carbonised condition, the pistons and cylinders will certainly wear more rapidly than otherwise. If an engine has done much work on dusty roads and no air cleaner has been fitted to the carburettor, the wear will be more pronounced.

Perhaps the best indication of excessive cylinder and piston wear is the running of the engine, for if there are piston slap, excessive carbonising, continual fouling of the plugs, loss of compression, excessive oil and petrol consumption, and a general loss of power on hills, these are signs that the cylinders need truing up and new pistons fitted. If it is found that after constant use the general performance of a car is appreciably lower than during the first few thousand miles, and, further, if the ordinary attention and adjustments, such as decarbonising, valve regrinding, tappet adjustment, and carburettor tuning, are of no avail, the symptoms point to wear in the cylinders.

A car, well treated and looked after, should run at least 30,000 to 40,000 miles before it is necessary to machine the cylinders and fit new pistons and rings. Many modern engines with alloy-iron cylinder blocks or liners will run for at least double these mileages before such reconditioning is necessary.

How the Cylinder Wears

It is important for the motor engineer to remember that the working part of the cylinder barrel does not wear evenly, so that it is necessary to measure it at a number of different places. If, for example, the cylinder is measured at the bottom side, i.e. nearest the crankshaft, it will be found that there is practically no wear at all, but if measured a little above this at a position corresponding to the lowest part swept by the piston rings, a slight ridge effect will be discovered. Fig. 427 shows graphically the characteristics of cylinder wear in relation to piston travel, as measured on a number of motor-omnibus engines. It will be seen that the wear is practically entirely confined to the piston-ring track, and that maximum wear in all cases occurred at the top, opposite the top piston-ring position, decreasing to about one-third at a distance equal to half the piston travel. The reason why the greatest wear occurs near the top of the piston's stroke is, of course, that the greatest piston thrust occurs at this part. Not only is the explosion pressure's effect at about a maximum here, but the thrust of the connecting rod is also at its most favourable value.

Further, it has been shown by numerous motor engineering laboratory tests that part, at least, of this excessive wear near the top of the piston's stroke is due to corrosive action of the combustion products and gases formed during the warming-up process on the metal of the cylinder walls.

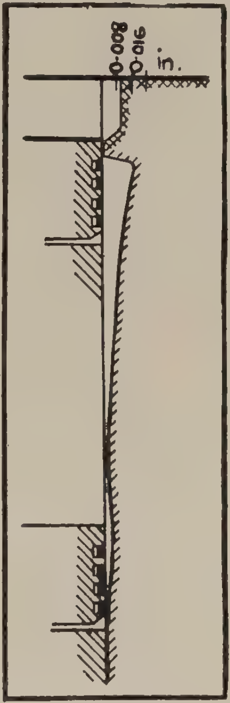


Fig. 427.—Showing (to an exaggerated scale) the manner in which the Cylinder wears.

Reducing Cylinder Wear

These wear effects can be minimised by:

(1) Using chromium-plated cylinder barrels; in some cases only the upper half need be thus treated. Porous chromium deposits such as those obtained by the Listard (or van Horst) process give much better results than solid castings as the porous nature of the metal promotes better lubricant-holding properties.

(2) By employing an upper-cylinder lubricant containing colloidal graphite.

(3) By speeding up the warming-up process after starting from the cold, as by " fast " idling.

(4) By maintaining the cooling water at as warm a temperature as possible during normal running without risk of overheating. A cool-running engine wears more quickly than one operating at a higher temperature.

(5) By adequate cylinder-wall lubrication, i.e. providing an excess of oil to the walls and scraping off the surplus with suitable designs of piston rings.

(6) By proper crankcase ventilation to dissipate gas blow-by past the piston and preventing contamination of the lubricating oil.

(7) By reducing gas blow-by to a minimum. This necessitates the fitting of well-designed piston rings and suitable pistons.

(8) By using hardened alloy cast-iron or nitrided cast-iron cylinder liners.

Notes on Cylinder Wear

From the previous considerations it follows that the cylinders of petrol and Diesel engines which have seen long service not only wear tapered with the larger diameter near the top but also tend to wear oval, due to the greater thrusts in the direction perpendicular to the gudgeon-pin axis.

The difference between the maximum and minimum worn diameters may be appreciable. In a typical example a cast-iron cylinder gave ·015 in. wear at the top and only ·003 in. at the bottom of the stroke, opposite the top ring position.

Plain cast-iron cylinders show an average wear of one-thousandth inch per 2,000 to 3,000 miles of running.

Nitrided cast-iron (Nitralloy) cylinder liners give from 7,000 to 10,000 miles per one-thousandth inch wear.

Chromium-plated cylinders show from 8,000 to 11,000 miles per one-thousandth inch wear.

American car-engine cylinders of nickel or nickel-chromium cast iron and with well-designed pistons and rings and adequate lubrication normally give from 5,000 to 7,000 miles per one-thousandth inch wear.

It has been demonstrated in the laboratory that when using dust-free air to the carburettor and with good cylinder and piston design engines can be operated so as to give as much as 100,000 to 140,000 miles per one-thousandth inch wear.

The greatest cylinder wear occurs *during the first few thousand miles* due to the wearing down of the fine machining ridges on the walls, rings, and pistons. Thus in a typical case the average wear per one-thousandth inch, over the first 10,000 miles of a new engine, was 3,300 miles; over the first 30,000 miles, 4,300 miles; over the first 50,000 miles, 5,600 miles, and over the first 80,000 miles, 6,700 miles. The importance of a fine surface on the pistons, rings, and walls in the case of new or rebored cylinders is here clearly emphasised. The better the surface finish the less will be the initial and also the total wear over a given distance. There is, however, a limit to the degree of surface finish, for if too fine, i.e. only a few micro-inches (millionths of an inch), the lubricant tends to become scraped off and there is a danger of metal contact with much-increased wear.

The amount of cylinder wear in a multi-cylinder engine is generally different in each of the cylinders over the same total distance of running. Thus, after 10,000 miles one or two of the cylinders may wear twice as much as the others. This is due to the unequal cooling effect of the cooling-system water, differences in lubrication to the cylinder walls, etc. *When an engine is to be measured for wear effects* each of the cylinders must be measured at several places and the cylinder showing the greatest wear taken as the standard to be rebored. The others are then machined to the same chosen diameter.

When to Rebore Cylinders

In general, in the case of car and commercial engines when the greatest clearance between the aluminium-alloy pistons and the cylinder walls due to wear is about ·008 in. the engine may be given *a further lease of life by fitting new piston rings* preferably using one of the modern spring-type piston rings, such as the Wellworthy "Simplex," or "Duaflex" for the bottom or middle piston grooves. A plain pressure ring should be used at the top. When the maximum clearance between the piston and cylinder exceeds ·015 in. a rebore is necessary. The maximum permissible clearance for engines of 15-h.p. R.A.C. rating and above is about ·020 in., at which value a rebore should certainly be given.

Fitting Oversize Pistons

When it is necessary to rebore, i.e. machine bore or grind, a cylinder block, the cylinder having the worst degree of wear should be rebored just enough to bring the bore parallel and slightly greater than the diameter of the cylinder at its position of greater wear, i.e. near the top. It should then be measured carefully to within a half-thousandth inch. Then, the sizes of the available *oversize pistons* supplied by the manufacturers of the engine, or firms of piston manufacturers, should be looked up and the cylinder bored out to the nearest oversize piston. These oversize pistons are always dimensioned in the manufacturer's lists as the diameters of the rebored cylinders they will fit, the correct clearances having been allowed by the piston manufacturers. Thus, if a cylinder has been rebored so that it has a diameter of, say, 2·750 in., then the oversize piston marked "2·750 in." will fit this cylinder with the correct working clearances. Actually, the diameter of the piston will be less than 2·750 in. by the amount of the clearance which must be allowed for the sliding fit and the difference between the thermal expansions of the aluminium piston and cast-iron cylinder, but the motor mechanic need not be concerned with such clearances in the case of commercial oversize pistons.

Generally, the car-engine manufacturer supplies stock oversize pistons to suit cylinders with rebored diameters greater than the original or new diameter, by ·0075 in., ·010 in., ·015 in., ·020 in., ·030 in., and ·040 in. The larger oversize pistons would be used for cylinders that have been rebored two or three times.

Usually, however, after a second rebore, when excessive wear occurs, a cylinder liner is fitted. The cylinder walls are sufficiently thick to enable such liners to be fitted after two normal rebores.

In summarising the above information it can be stated that after the cylinder bore having the worst wear has just been cleaned up parallel, it should be rebored (and preferably finish-bored) to suit the nearest available over-size piston diameter. All the other cylinder bores should, of course, be finished to the latter size.

Example of Car-engine Cylinder Rebore Sizes

In the Vauxhall Velox engine, when the cylinders are checked for wear the internal and external gauges recommended are used to measure the bores and piston diameters. If the cylinders have less than ·005 in. taper or wear they can be reconditioned satisfactorily by honing, and ·0005 in. oversize new pistons fitted. If more than ·005 in., they should be honed or rebored to the nearest oversize.

Pistons of each oversize are manufactured to a ·001-in. limit, and are available in two grades, designated "W" and "Y" respectively. All pistons of a grade of the same nominal oversize are made within ·0005-in. variation in diameter.

The diameter is measured immediately below the lower ring groove at right angles to the gudgeon-pin axis, the grading letter being stamped on the piston crown. "W" is for the top half-limit and "Y" for the bottom half-limit pistons. The standard or new piston sizes are as follows:

Piston grade "Y": piston diameter, 2·7345–2·7340 in.; cylinder bore, 2·7365–2·7360 in.

Piston grade "W": piston diameter, 2·7350–2·7345 in.; cylinder bore, 2·7370–2·7365 in.

Oversize pistons are made in the following oversizes, namely: ·005 in., ·010 in., ·020 in., ·030 in., ·040 in., ·050 in., and ·060 in.

Thus, if an oversize piston of ·030 in. is to be used the following will be the piston and cylinder actual dimensions:

Piston grade "Y": piston diameter, 2·7632–2·7627 in.; cylinder bore, 2·7650–2·7645 in.

Piston grade "W": piston diameter, 2·7637–2·7632 in.; cylinder bore, 2·7655–2·7650 in.

When new, the standard piston clearance is ·0015–·0025 in.

The oversize piston clearances are ·0013–·0023 in.

Maximum Rebore Diameters

Engine manufacturers invariably state the maximum permissible rebore diameters of their engines. In most instances the maximum increase in diameter above the new diameter lies between ·040 in. and ·065 in., and the oversize pistons supplied by the manufacturers do not extend beyond these limits. Particulars of the rebore sizes of motor-vehicle engines will be found in the Electrical Diagrams and Data Volume.

Methods of Truing Worn Cylinders

There is a number of methods in present use for truing worn cylinders, namely by *reboring*, *reaming*, *honing*, and *grinding*; we shall deal with each method in turn.

The Reboring Method

The method of truing worn cylinders by means of a boring cutter has become widely employed in recent years, on account of the rapidity with which the work can be done and also of the accuracy of the results.

The secret of the successful application of this method is that of using cutters having extremely hard cutting edges which last for relatively long periods before resharpening becomes necessary; the ordinary carbon and alloy tool steels previously used were not so satisfactory in this respect.

The modern cylinder-reboring machine employs one or more cutters, the cutting portions of which are tipped with tungsten-carbide or Stellite; these extremely hard cutting materials are greatly superior to high-speed tool steels.

Typical examples of tungsten-carbide tools are those known as "Widia" (A. C. Wickman, Ltd., Coventry) and "Ardoloy" (Alfred Herbert, Ltd., Coventry). Since these materials are expensive, they are only used for making the tips of the cutters, the shanks being of carbon steel.

Cutting Speeds and Feeds

The cutting speeds of tungsten-carbide tools range from 300 to 400 ft. per minute, and when used for the boring bars of cylinder tools the cutters usually rotate at speeds of 250 to 400 r.p.m. The feeds employed with these cutters, for motor-vehicle cylinders, are from ·002 to ·006 in. per revolution of the cutter.

The depth of cut varies according to the diameter of the cylinder bore and upon the type of machine employed; also upon the number of cutters used in the boring bar.

The average depth of cut taken with these cutters is ·05 in. When a worn cylinder is to be bored out *for the purpose of taking a cylinder sleeve*, or liner, a greater total quantity of metal (usually from $\frac{1}{8}$ to $\frac{3}{16}$ in.) has to be removed, so that a series of cuts, each of about ·05 in., should be taken until the final size is reached.

For the best results in the case of cylinder rebores, a roughing cut of ·05 in. should be taken and, if all the metal is cleaned up, i.e. none of the old bore surface is left. This is followed by a finishing cut of ·002 in. to ·004 in., using a finer feed than for the first cut.

Boring Bars

The cylinder-boring machines all employ rigid cylindrical boring bars to carry the cutter head. These bars are mounted in strong brackets or housings which are clamped to the cylinder blocks, using either the cylinder-head studs, or long bolts, nuts, and plates, the former passing through the barrels of the adjacent cylinders.

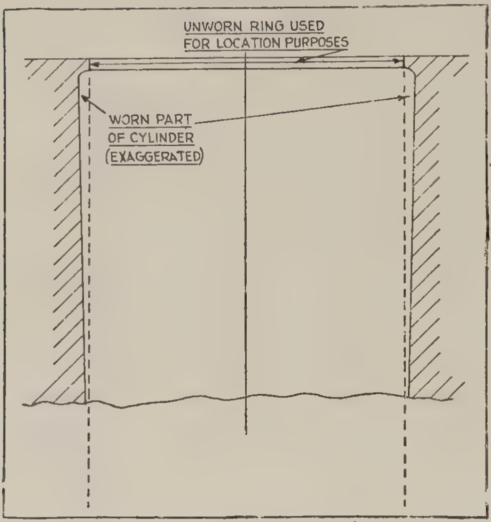

UNWORN RING USED FOR LOCATION PURPOSES
WORN PART OF CYLINDER (EXAGGERATED)

Fig. 428.—Showing Unworn Cylinder-barrel Ring.

The boring bar is driven by an electric motor and provided with a square-thread nut and screw feed, so that the cutter descends through the cylinder barrel in a spiral path. An automatic stop is usually provided for switching off the electric motor when the bar reaches the bottom of the barrel.

The finish obtained with tungsten-carbide cutters is sufficiently smooth for aluminium pistons to work in, but careful examination of the finished bore will reveal a definite tool-mark spiral impression. For the best surface-finish results, it is usual to finish-hone the cylinder bores which have been machined with cutters of the type described. This method removes the very small ridges left by the cutters and gives an excellent surface for the piston to work with.

The cutter head must be accurately located in respect to the cylinder bore. For this reason, most machines are provided with *locating rings*, made to fit the cylinder barrel, and having central holes for the pilot end of the cutter bar.

In connection with the use of these locating jigs, it should be noted that, owing to the fact of the top piston not reaching the top of the cylinder barrel, *a practically unworn ring* is left above the highest point reached by the top ring in its travel. This ring (Fig. 428) can therefore be used for locating the cutter bar.

Removing the Unworn Ridge

Special tools are now available for removing the unworn ridge at the top of the cylinder barrel before fitting new piston rings or reconditioned pistons. These tools are provided with locating pilot members to ensure that the ridge metal is machined concentrically with the cylinder axis. A single or multiple cutter of high-speed steel or tipped with tungsten-carbide is employed for the actual machining. The tools in question are generally hand-operated.

Fig. 429 illustrates the Hall cylinder-ridge reamer.[1] This is inserted in the top of the cylinder until the three rollers (two ofwhich are shown) contact the wall of the cylinder below the ridge and thus act as a pilot member to locate the cutting tools concentrically with the bore. A few turns, by hand, of the tool with a ratchet spanner will then remove the ridge. The tool ceases, automatically, to cut when the ridge has been cut flush with the cylinder wall. It is supplied in three sizes, namely, $2\frac{1}{8}$-3 in., 2·6-4 in., and 4-5 in., respectively.

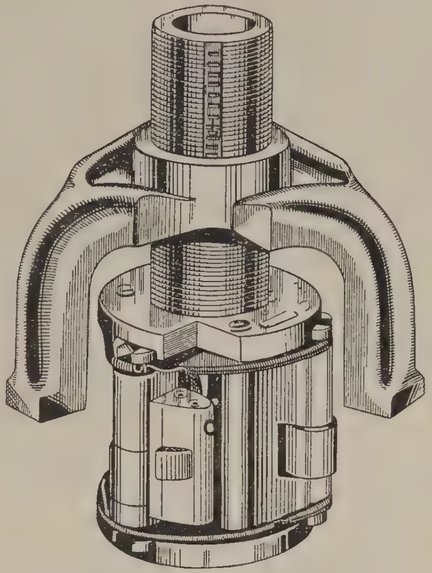


Fig. 429.—The Hall Cylinder-ridge. Remover.

Sharpening Tungsten-carbide Cutters

Owing to the extreme hardness of tungsten-carbide, it cannot be ground with ordinary emery or carborundum wheels, although one or two special grades of abrasive wheels have lately become available.

The method employed for sharpening these cutters is to use a cast-iron wheel charged with diamond dust, the tool surfaces being lapped, as it were, with this abrasive. A little oil is used to hold the diamond dust. A light pressure only should be employed when sharpening the cutter.

Typical Boring-tool Procedure

As an example of the procedure adopted for the reboring of a modern engine cylinder block, the Vauxhall Velox and Wyvern engines will be considered. If the out-of-round and taper effect do not exceed ·005 in., the cylinder can be reconditioned by honing alone; otherwise boring, followed by fine honing, is recommended.

Before reboring, the cylinder block should be washed thoroughly in a paraffin bath or degreaser; if a chemical degreaser is used the inside of the crankcase should be repainted with a non-flaking enamel, e.g. Engenamel.

Accuracy in boring is emphasised, so that the boring tool setting gauges should be *checked regularly with master gauges.* The cutting tool should be checked after each cut, and fusion of cast iron cleaned off the tip with an abrasive slip. The cutting tool should always be diamond-lapped before taking the second cut. The cylinder-bore finish obtained by use of the boring tool only does not meet the requirements of the high wall pressure rings in Vauxhall engines. Unhoned or unground bores can only result in rapid ring wear, with the associated troubles of premature excessive oil consumption and oiling-up of sparking plugs. All bores, therefore, should be hone-finished to obtain the necessary quality of cylinder-bore finish.

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[1] Morris Ingram Ltd., London.

Before using any type of boring bar, the face of the cylinder block must be cleaned with a flat file and a strip of emery cloth to remove any dirt or burrs. Determine from the piston carton label the finished bore diameter. If the label is damaged the finished bore diameter can be determined by reference to the manufacturers' specifications.

Note.—The finished bore diameter should be achieved by taking two cuts with the boring bar, a rough cut and a finishing cut, and then finally honing.

First Cut.—Set the boring bar to cut within ·004 in. (·102 mm.) to ·005 in. (·127 mm.) of the finished bore diameter.

Second Cut.—Set the boring bar to leave ·0005 in. (·0127 mm.) to ·001 in. (·0254 mm.) to be removed by honing, the final operation. Before honing, the block must be thoroughly blown out with an air line and cleaned of all boring dust. Stones classified as "fine" must be used when honing, using paraffin as a lubricant.

With bores finally honed to the correct size for the grade of piston to be fitted, check them for out of parallelism and ovality, using a cylinder gauge. Clean the bores thoroughly with a clean dry rag before the pistons are fitted.

Note.—After reboring, clean all oilways by means of air blast. The cylinder block and pistons should be washed in paraffin before reassembly of the engine, and any rag used must be of a non-fluffy nature.

Typical Cutter-type Boring Machines

The machines used in motor garages and reconditioning works are generally of the portable kind, so that they are used on the cylinder block in its chassis. It is necessary in some (but not all) cases to remove the radiator and the bonnet stay rods for convenience of operation. The sump should also be removed, and some provision made to protect the crankshaft bearings against the borings that fall from the cylinders.

There are several efficient portable boring machines on the market, of which the Van Norman "Per-fect-o,"[1] the "Storm,"[2] and the "Hall"[3] are typically examples.

The Van Norman machine, shown in Fig. 430, is of the single-cutter kind tipped with an extremely hard material known as "Carboloy"—this material is so hard that *it will cut glass*; it is sharpened on the machine itself by means of a revolving disc charged with diamond dust.

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[1] E. P. Barrus, Ltd., Brunel Road, Acton, London, W.3.

[2] Buma Engineering Company, Ltd., Newcastle-on-Tyne.

[3] Brown Bros., Ltd., Great Eastern Street, London, E.C.2.

The cutter revolves at a moderate speed and leaves a finish considered satisfactory for the direct fitting of pistons.

The tool-cutter is set to the exact diameter required (Fig. 431) by means of a micrometer so that cylinders can be rebored to exact dimensions within the accuracy of setting (or reading) the micrometer.

The shaft or column on which the cutter blade is mounted revolves inside another column which does not revolve but which goes up and down with the feed of the bar. At the cutter end of this non-revolving column, just ½ in. back of the cutter blade, is a "catspaw" or four-bladed support (Figs. 432 to 434). This catspaw is expanded and contracted by means of a hardened and ground scroll controlled by a knob at the top of the bar. This enables the operator to use this catspaw for centring in any part of the cylinder. When the bar is boring, the catspaw blades are expanded so that they ride down without rotating through the length of the cylinder on the new, freshly

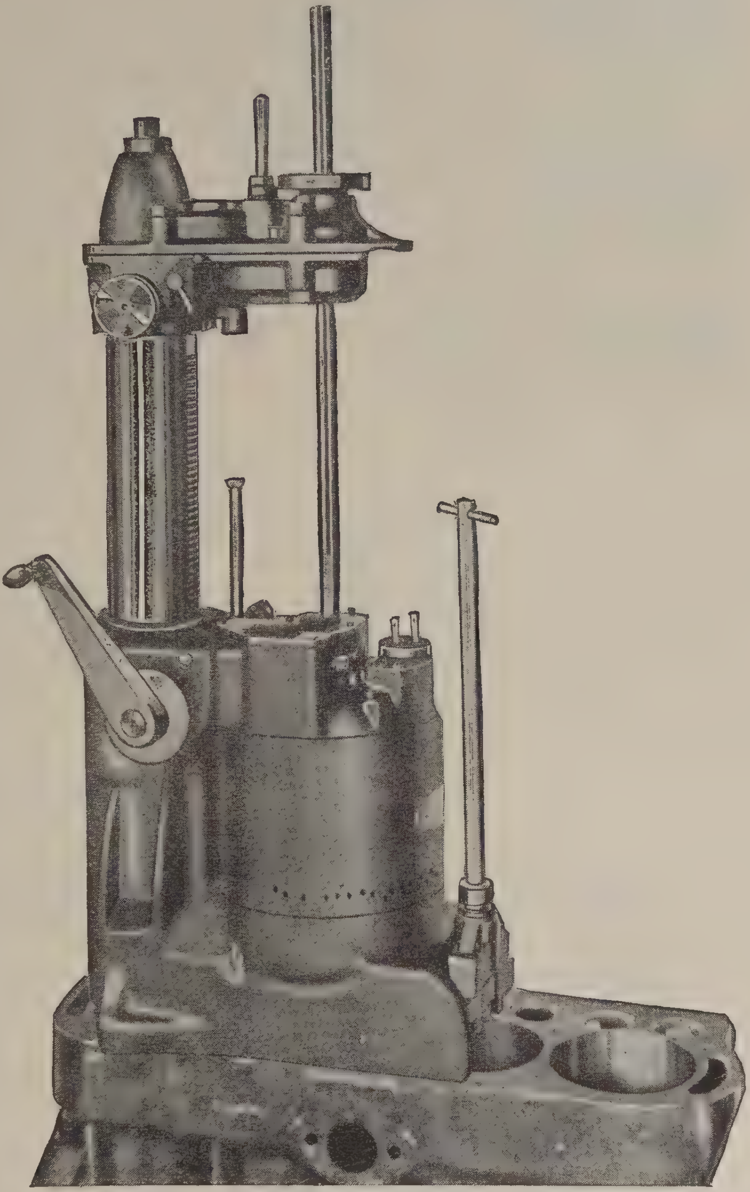

Fig. 430.—The Van Norman Cylinder-boring Machine.

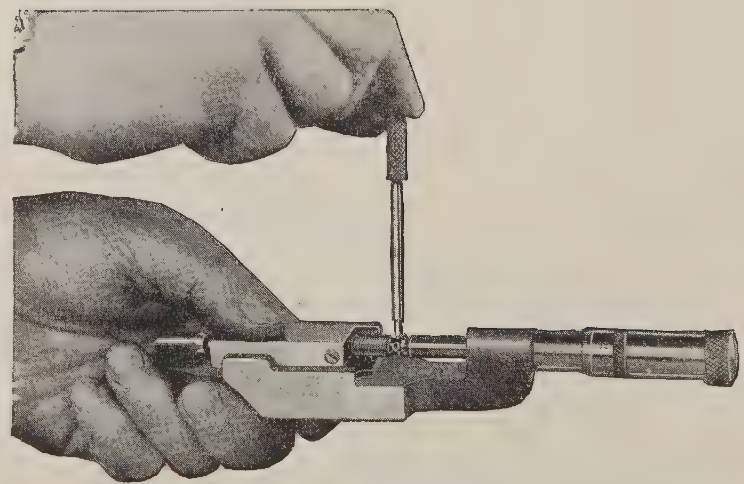

Fig. 431.—Showing Method of setting Cutter with Micrometer Gauge.

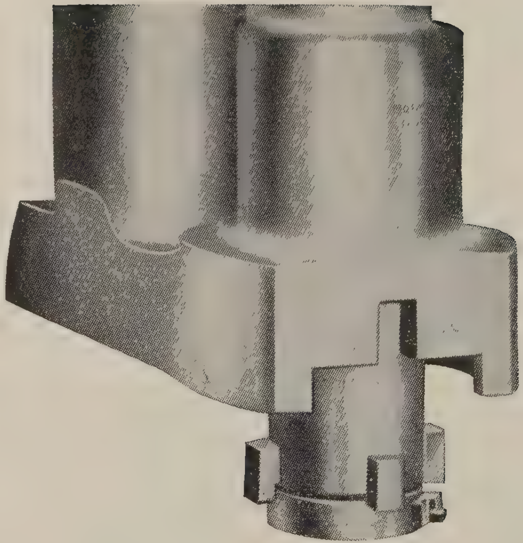

Fig. 432.—The " Catspaw " Centring Device.

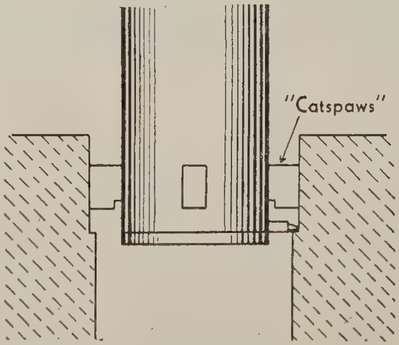

Fig. 433.—The " Catspaw " Device in Action.

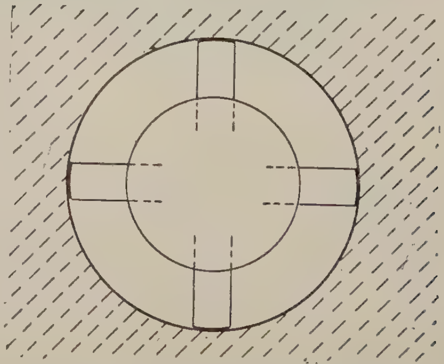

Fig. 434.—Plan View of Cylinder showing " Catspaw " Device in Position.

cut metal, assuring a cylinder wall free from chatter and a cylinder which cannot help but be absolutely round and straight.

The Van Norman boring bars are made in several models, including the 777-S "Per-fect-o" with a range of cylinder bore capacities of 2·6 to 5·343 in. This has two cutter speeds, 375 and 220 r.p.m. for small and large cylinders, and two feed rates, $2\frac{1}{2}$ in. per min. and $1\frac{1}{2}$ in. per min.; cuts up to ·050 in. can be made. Smaller boring bars, the 943-S and 944-S are available; these with the bore capacity of 1·9 to 3·81-in. and 2·2 to 4·26-in. respectively. The larger boring bars are the "Giant Per-fect-o" for Diesel and other engines with capacities up to 9 in., and a four-speed model for hardened cylinders and liners.

The anchoring of the boring-bar machine is ingenious. Referring to Fig. 435, the anchoring unit is placed in the cylinder adjacent to that which is to be bored. It has a step to engage with the lower machined face of the cylinder block. The cam lever shown is expanded against the opposite wall by means of the inclined screw. The vertical anchor screw is then adjusted to the proper height and the anchor clamp slides over the top of the anchor screw—the screw head locating in a T-slot. The anchor clamp slides into the bar base and a few turns of the screw handle locks the boring-bar casting rigidly to the cylinder block. It will be observed that no clamping nuts, screws, straps or plates are used. A single screw with a tommy-bar tightened on the anchoring block provides a fully satisfactory clamping action; it requires only 1 to 2 mins. to centre the boring bar and lock it in position ready for boring.

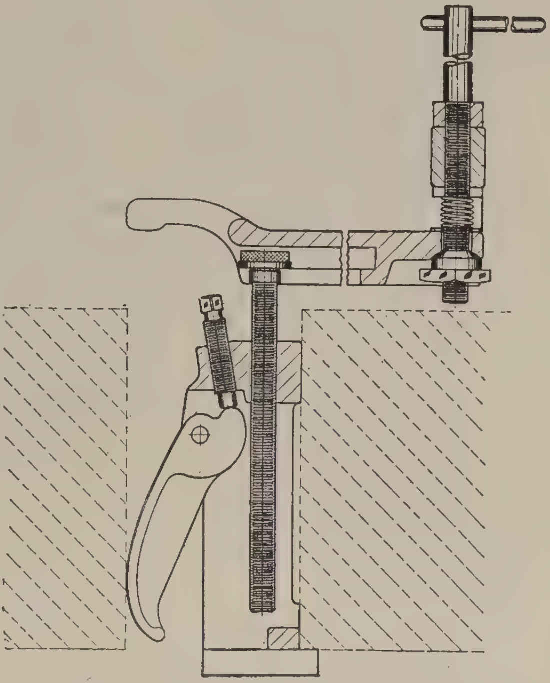

Fig. 435.—Method of anchoring Van Norman Boring Machine.

An automatic stop is provided to limit the travel to suit the cylinder-barrel length.

The manufacturers issue an excellent instruction book on the care and operation of the Van Norman "Per-fect-o" boring bars so that it is not necessary here to describe the detailed operation of this machine.

The "Storm" boring machine, illustrated in Fig. 436, uses a single tungsten-carbide cutter, and will take a cut of ·06 in. depth with a very satisfactory finish.

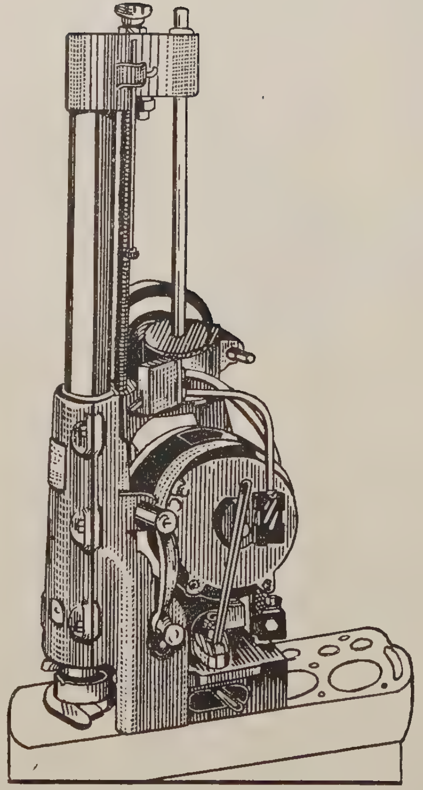

Fig. 436.—The "Storm" Cylinder-boring Machine.

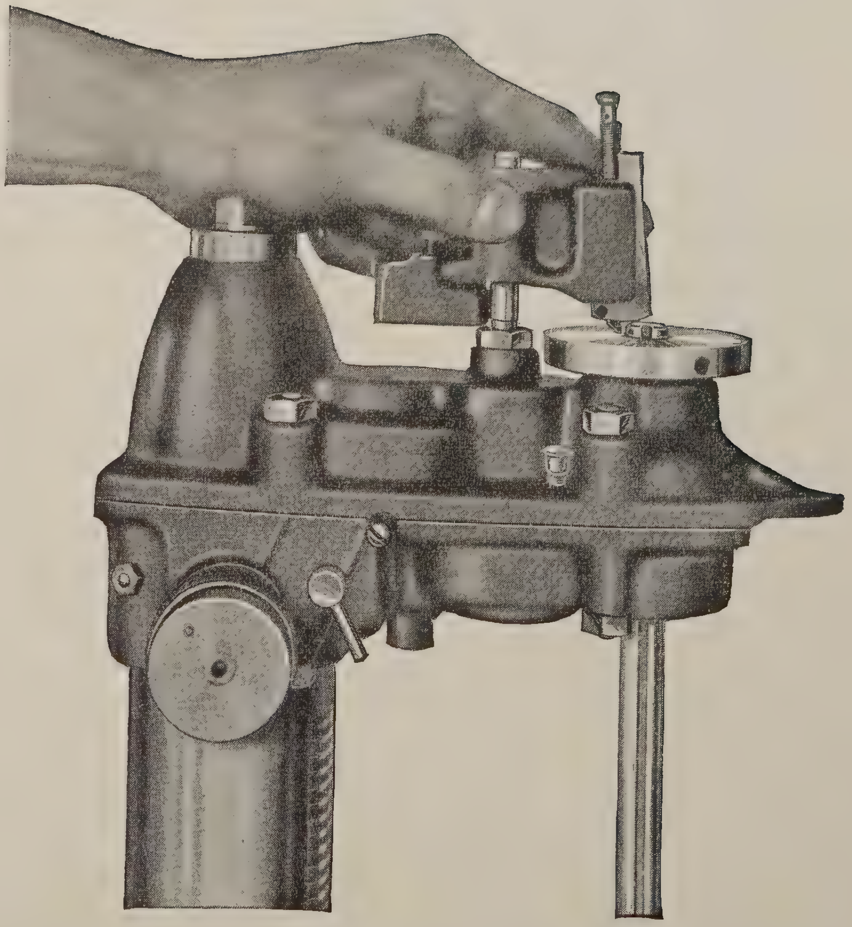

Fig. 437.—Showing Method of sharpening the Cutter by means of a Disc charged with Diamond Dust and Oil.

The machine has a massive main bar, ground to accurate limits and smoothly finished. An electric motor of $\frac{1}{4}$ h.p., operating from grid supply voltage and cycle frequency, is used to drive the cutter head through helical gearing. The positive-screw feed for the cutter head is equipped with a unique method of engaging and disengaging the feed through the agency of an eccentrically operated split nut. The cutter bar has a quick-action return, employing a pinion and rack for this purpose.

The machine is provided with long adjustable main bearings which give ample support to the bar, even when boring the longest cylinder.

The machine has a special micrometer for setting the cutter whilst the latter is in position in the boring head.

A projecting pin in the body of the micrometer fits into the centre of the cutter head and is held in position by a spring-loaded ball which fits snugly into a circular groove in the cutter head. This allows the micrometer to be moved around the cutter head until the projecting end of the slide on the micrometer touches the front face of the cutter. By this means the cutting-point is always in the centre line of the micrometer, which ensures a correct reading irrespective of whether the front face of the cutter has been thrown out of the centre line of the cutter holder after honing or grinding.

Another special feature is the provision of a three-point centring device. One centring head is provided to cover the capacity of 2·2 in. to 4·2 in. The three blades are permanent fixtures and cannot be over-expanded. This is a distinct advantage over centring heads where the blades have to be changed over to suit different bore sizes. There is no danger of the blades becoming loose or damaging the scrolls when fitting. The centring head is entirely separate and is fitted over the cutter head and removed after centring and clamping down the machine. By this method of centring, the cutter holder need only be removed from the cutter head for sharpening, as the machine can be centred without first removing the cutter holder.

A special device is fitted to prevent chattering when using the machine for boring cylinders having connecting-rod slots.

In the model shown, the feed can be cut out while the machine is actually cutting by slackening the screw provided for this purpose. This allows the feed screw to revolve, so that, if the necessity arises, the feed can be cut out without stopping the motor.

The electric motor drives the cutter-head gearing through a belt and pair of pulleys, the belt having an efficient guard. With this arrangement the motor can readily be removed and refitted should necessity arise; moreover, the motor is hinged to enable the belt to be tightened.

The diamond sharpening disc for the cutter is integral with the upper pulley; two jigs are supplied for holding the cutter assembly when re-sharpening the different faces of the cutter.

The more recent Buma "Cent-Ro-Mic" cylinder-boring machine (Fig. 438) embodies several interesting features. The cutter head and high-speed spindle are mounted on Timken roller bearings in the glass-hard bar which is

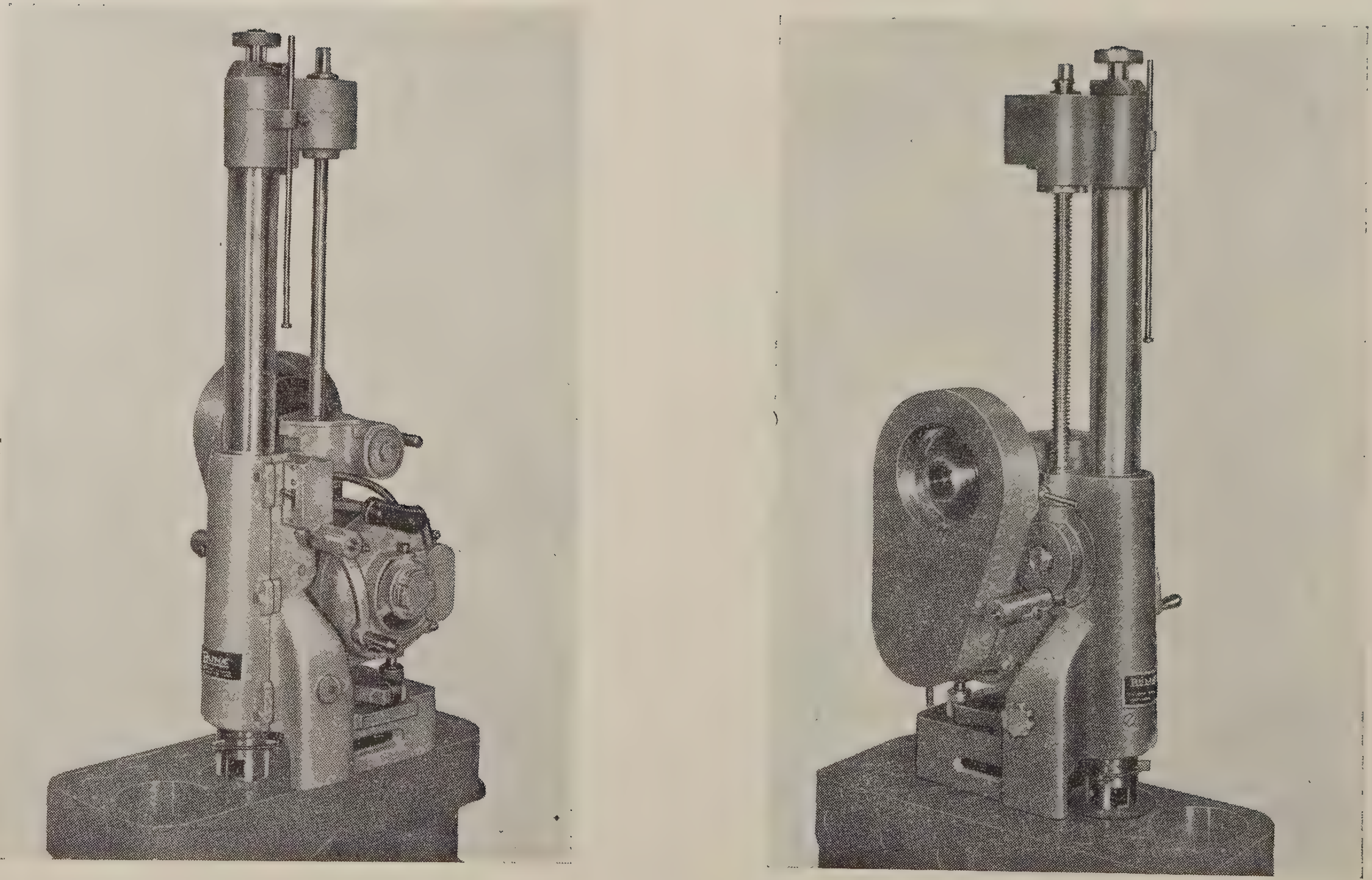

Fig. 438.—The Buma "Cent-Ro-Mic" Cylinder-boring Machine.

guided straight through the bore by the base casting, which is of rigid construction with long adjustable bearings. It produces a perfect bore in one cut without the use of steadies or followers. The machine can be set instantly on the cylinder block by lowering the main bar into any desired position in the main bore. The centring blades are expanded by turning the hand wheel at the top of the gearbox. The clamping is both quick and positive in action, and on the smallest cylinder block the machine can be clamped from the adjacent bore; this is a distinct advantage when boring cylinder blocks on chassis. An Acme thread screw provides a uniform and accurate feed downwards to the main bar. A long solid phosphor-bronze nut is in constant engagement with, and rotates, the screw. By pulling over a small lever the feed can be engaged and disengaged at once, whilst the machine is running.

A neat design of micrometer for setting the cutter to the exact cutting diameter is supplied with the machine. The cutter holder is mounted on the micrometer so that the cutter is set away from the machine. The micrometer is provided with a pin which fits into a hole in the cutter holder, thus locating the latter with absolute accuracy. The micrometer is fixed in the cutter adjuster, the cutter is pushed out to the end of the micrometer head and then locked in position; the micrometer is, of course, set to the required boring diameter beforehand. The machine, which is driven by a $\frac{1}{4}$-h.p. motor, has a boring range of 2·2-in. to 4·2-in. diameter and length up to 10 in. It uses tungsten-carbide cutters and has a diamond lap.

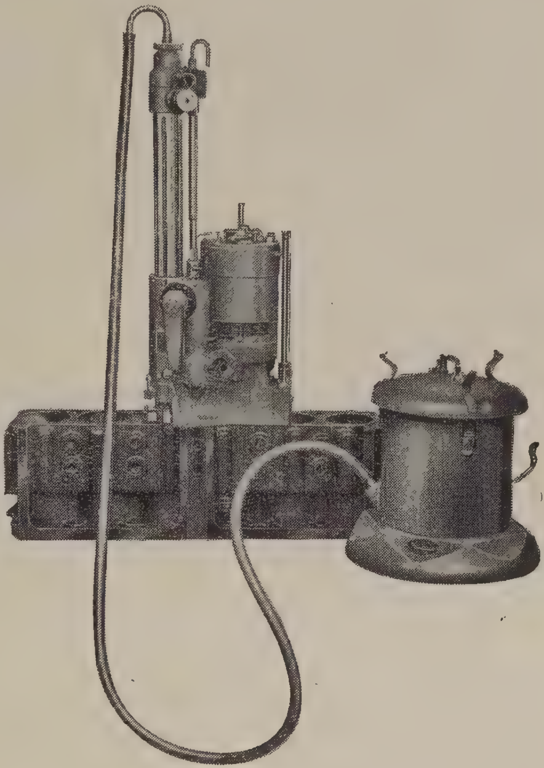

Fig. 439.—The K.B. Cylinder-boring Machine, with Hydraulic Drive.

The K.B. boring machine (Fig. 439)[1] in its modern redesigned form possesses several novel features, including an hydraulic flexible unit which can be located on the bench or floor away from the cylinder block and connected to the latter by means of a length of flexible drive. This floor unit consists of a $\frac{1}{2}$-h.p. A.C., D.C., or universal electric motor. The boring machine has a three-speed gear, enabling the cutter to operate on cylinder bores of all sizes, from 2·2 in. to 4·625 in. at approximately the same surface cutting speed, namely 400 ft. per min.; a tungsten-carbide cutter is used. The machine employs an hydraulic feed for the boring bar which can be varied by a simple means of control to any desired rate of feed.

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[1] C. Barton Giles, Trafalgar Sq., London, W.C.2.

The worm gearbox is located on the top of the main spindle. The latter can be raised quickly by lifting a ball handle on the oil reservoir and briskly pumping oil into the spindle bearing.

The cutter head is not rigidly attached to the main spindle, the drive being taken through a spring pin, damped by a compression spring and cork washer. The machine is supplied with a micrometer, which forms an integral part of the machine and not only allows the cutter to be set directly to size, but allows it to be checked at any moment during reboring.

Another feature is the use of packing pieces under the machine, which avoids the necessity of removing the cylinder-block studs in most cases.

A lapping plate and jig for sharpening the cutter are provided.

The machine, which, on account of the separate power unit, is much lighter than most other makes, weighs 60 lb. It will take a maximum cut, for cylinder-liner purposes, of ·125 in. (on the diameter), which, it will be seen, enables the usual cuts of ·02–·03 in. to be taken with comparative ease. The maximum length of bore that can be dealt with is 10½ in.

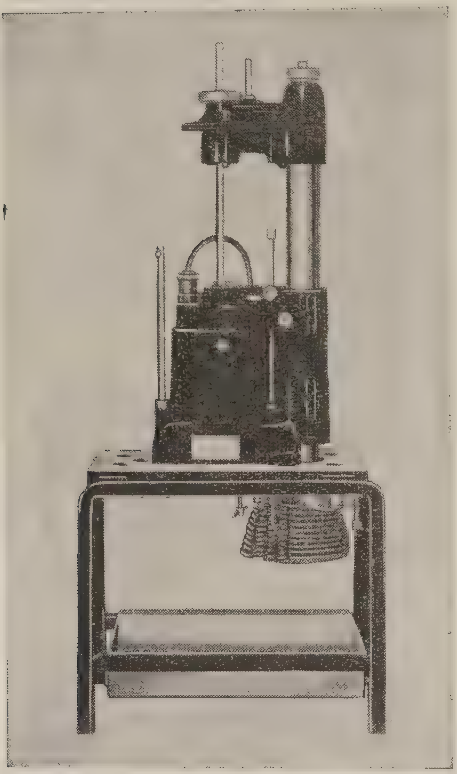

Fig. 440.—The Dyson Boring Stand for Motor-cycle Cylinders.

Motor-cycle cylinders can be rebored with the Van Norman-type machine with the aid of the Dyson boring plate and stand (Fig. 440). In this case the cylinder is mounted underneath the machined parallel face plate and is bored from the bottom or crankcase end of the cylinder towards the cylinder-head end. A simple clamping device using four quickly manipulated clamps holds the cylinder securely. The clamps swivel laterally, thus enabling the cylinder to be gripped at convenient points. Tommy-bar tighteners are provided so that no spanners are necessary. The stand is arranged to take the standard Van Norman boring machine single-action clamping device as used with automobile cylinder blocks.

The Dyson boring plate can also be used for reboring the cylinders of small aircraft-engines, air compressors, lawn mower and agricultural engines, pumps and hydraulic units.

Motor-cycle cylinders are often bored horizontally, using a special jig which holds the cylinder by the plain barrel portion. A single cutter of the tungsten-carbide-tipped pattern is used, as shown in Fig. 441, for the boring operation. The machine illustrated is the Heald Red Head one.

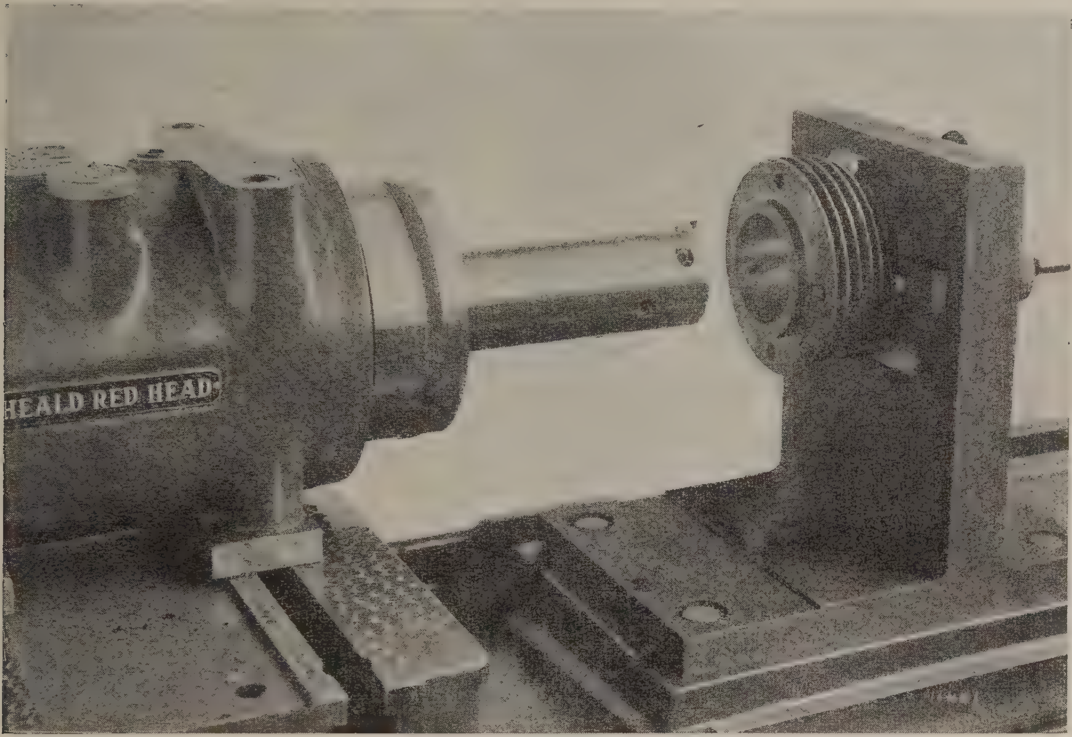

Fig. 441.—Boring a Motor-cycle Cylinder with a Heald Single-cutter Bar.

Machine for Routine Cylinder-boring Work

Whilst the portable-type cylinder-boring machines are well suited to the requirements of motor-vehicle-engine servicing establishments, it does not always provide the best solution where the boring of worn cylinders is a frequent or routine procedure, as in the case of large transport companies and others specialising in the general overhaul and reconditioning of similar vehicles or engines. Thus a large municipal transport undertaking generally employs vehicles of the same type, and its repair shops are equipped for dealing with engines off their chassis. In such cases the special machines are of a heavier and more robust nature, designed to deal quickly and accurately with similar components.

One such machine is that for reboring worn cylinder barrels of commercial-vehicle and other types of petrol and Diesel engine. Fig. 442 illustrates a suitable machine, by Kitchen & Wade Ltd., which is made to accommodate any cylinder block from that of a small car to that of a large lorry. It has a series of interchangeable boring heads, or "spindle snouts," and uses single-point tungsten-carbide boring tools.

Provision is made for no less than nine spindle speeds, namely from 130 r.p.m. to 1,450 r.p.m., and four rates of spindle feed, namely $\frac{1}{2}$, $\frac{3}{4}$, $1\frac{3}{8}$, and $2\frac{1}{4}$ in. per min. at any of the spindle speeds. An automatic trip motion is arranged in order to stop the feed with or without stopping the spindle rotation, as required.

The sliding head is of the balanced type, and the spindle is of very rigid design. Four spindle snouts are included, each being of the self-contained unit assembly type. Precision tapered roller bearings, which take all the cutting pressures, ensure an extremely high degree of rigidity and therefore accuracy in cylinder-boring operations. Other features include pressure or splash lubrication of the gears by means of a built-in oil pump; a compound-movement work table; built-in illumination for the working area; quick and fine adjustments for the sliding head; and the provision of covered slideways.

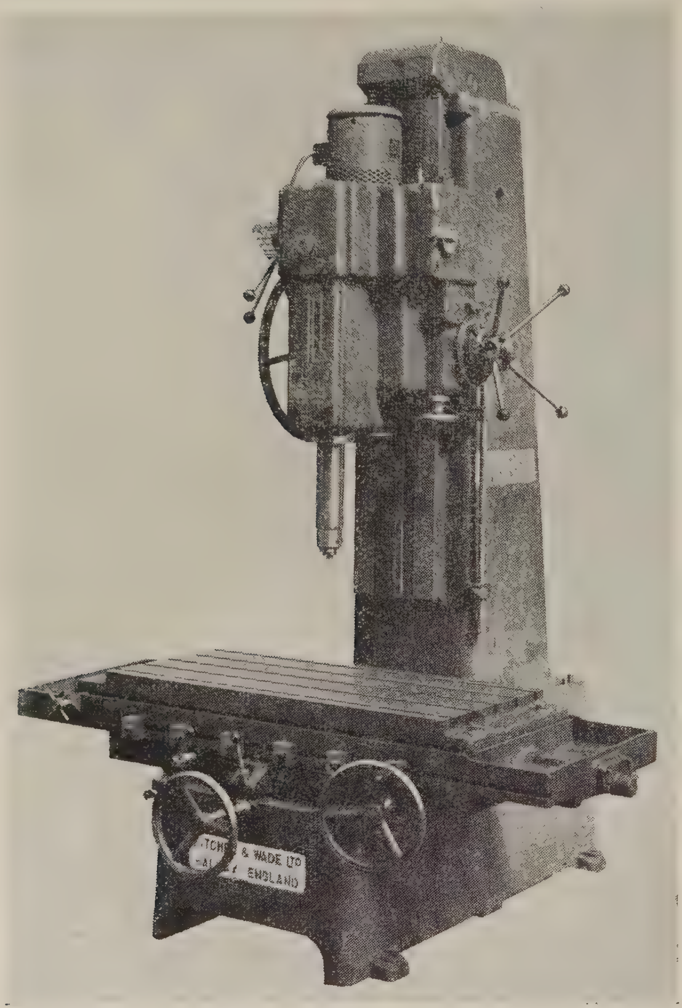

Fig. 442.—The Kitchen & Wade Cylinder-boring Machine.

Finishing Cutter-bored Cylinders

With a keen-edged tungsten-carbide cutter, a completely rigid design of cylinder-boring machine and suitable depth of cut and rate of feed, the surface obtained is a very good one and is considered by some authorities to be quite satisfactory for direct use. In one well-known design of machine cylinders which are not badly worn can be bored in a single cut of ·015 in. to ·020 in., with a well-finished surface suitable for use without any additional treatment. The rate of feed for a cutter speed of 400 r.p.m. is 2½ in. per min., i.e. $\frac{1}{160}$ in. per rev., and this produces a smooth finish.

If, however, the contours of a rebored cylinder are examined under a microscope, they will be found to consist of a regular series of sharp ridges and grooves, and during the first few thousand miles of an engine's life the tops of the ridges become worn down, so that the piston clearance becomes greater. Tests have shown that, on this account, the rate of wear is much more for the first few thousand miles than during the normal running period; the life of the cylinder is therefore reduced.

It is for this reason that the fine-hone finishing process is recommended, since it removes the sharp crests left by the boring cutter and leaves the surface in the "run-in" condition. Usually from ·002 in. to ·004 in. is left on the rebored cylinder for the subsequent honing process. Engine cylinders thus finished have a very much longer useful life before reboring becomes necessary. Incidentally, this method is used in the original manufacturing process for finishing cylinder bores.

There is, however, no unanimity of opinion amongst experts as to the ideal surface finish, but it is generally agreed that too fine a finish, i.e. a mirror-like surface as obtained by superfinishing, is not desirable as it is difficult for the metal to "hold" the lubricant.

When finish honing is employed it is important to wash out the cylinder bores thoroughly with paraffin in order to remove traces of the abrasive particles from the hones.

Removing the Swarf during Reboring

In order to remove the dust and chips from the cutter point when reboring a cylinder block *in situ*, a special device known as the Van Norman "Vacuum Chip Remover" can be employed on "S" series boring bars with hollow main columns. It consists (Fig. 443) of a high-velocity multistage vacuum unit which is connected by a hose to the top of the hollow boring bar and thence through the bar to a small casing or hood on the cutter head. The hood concentrates the suction effect on the point of the tool, thereby removing the swarf and at the same time keeping the tool clean. The arrows show the path of the air current which takes the swarf into the vacuum unit on the right.

Notes on Boring-bar Machines

In most cases it is necessary to remove all of the cylinder-head holding-down studs from the block in order to accommodate the boring-bar mounting. Special quick-action stud removers are now supplied by some manufacturers of reboring machines for this purpose.

Special attention should be given to the initial centring of the boring head and in this connection the unworn ridge at the top of the cylinder block is generally employed for this purpose.

It is important to check whether the top machined face of the block is absolutely at right angles to the cylinder bore as cases are occasionally met with where this is not so. The use of a precision square and feeler gauge blades is recommended as a means of checking for squareness of the bores with the upper machined face.

For fitting sleeves into cylinder bores that have already been rebored twice special boring bars are now available which will take cuts up to $\frac{1}{16}$ in. at a time.

In one design of boring machine, in addition to the boring head there is also a grinding spindle driven at a high speed from the motor, so that a cylinder can be rebored by cutter and finish-ground at a single setting of the machine.

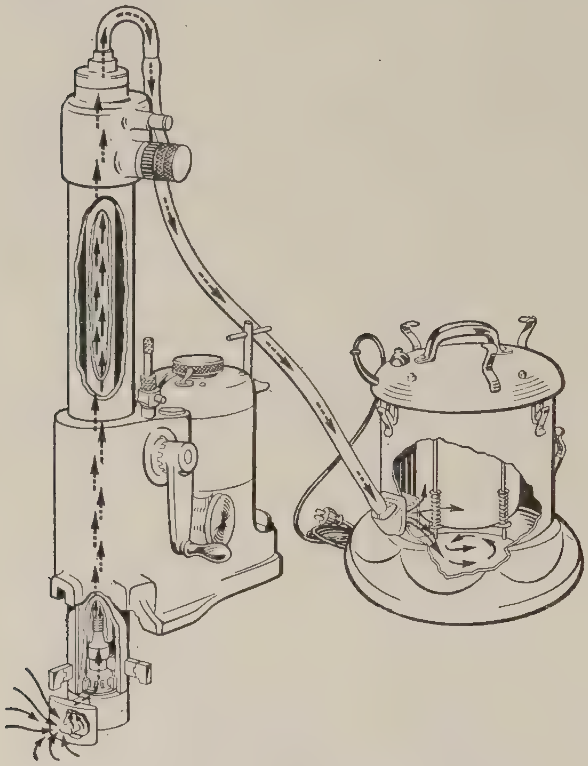

Fig. 443.—Showing Principle of the Van Norman Swarf Remover.

In regard to finishing with cutter-type boring machines, a heavier cut with coarser feed is used to remove the surplus metal for cleaning-up purposes, followed by a finer cut with a finer feed for finishing.

Cylinder Reaming

This method consists of removing the surplus material not by a single steel-cutting tool, but by a series of such tools, or cutters, mounted in a cylindrical body or tool head. In this case some of the drawbacks of reboring are experienced in connection with the actual finish of the surface. The latter is left in a minutely irregular condition consisting of a number of high and low spots caused by the slight "tearing" action of the cutting tool. When these high spots have worn down, after the engine has been working for some time, the correct working or bearing surface will then be obtained. Since, however, the depths of these hollows, or markings, are of the order ·001 in. to ·003 in., it will be seen that a fair amount of clearance will result by the time the piston and cylinder are bedding properly; this is equivalent to taking a few thousand miles' running off the life of the engine.

The tool marks left by the reaming process should not be visible, but even in this case the surface material when seen under a low-power microscope will be found to be relatively rough and porous as compared with the polished surface before the reaming process.

When there are no facilities for grinding—a process which, as we shall show later, gives the finest surface finish—reaming is probably the best alternative where there is much truing-up of the cylinder bore required.

A typical cylinder-reaming machine has a six-cutter tool head, all of the cutters being held at the exact radius required. They are adjustable to different radii by means of a single screw. The cylinder-reaming method has now been replaced to a considerable extent by the boring-machine one previously described.

In a typical case of cylinder reaming, used by a large motor-car manufacturer, the cylinder bores were finish-reamed at 30 ft. per min. cutting speed with a feed of $\frac{1}{8}$ in. per revolution. The bores were thus reamed round and parallel to within ·0005 in., free from surface marks or chatter effects. A final polish honing operation gave a very fine surface finish.

The Lapping Process

Although at one time the lapping process was advocated as a means of truing worn cylinders, experience has shown that this method does not produce a true cylinder, although to some extent it reduces the out-of-round and tapered effect. In any case, it is a somewhat laborious method, even when the work is done on a lapping or stroking machine.

Lapping is nowadays confined to the production of a higher degree of surface finish than can be obtained by fine honing, and it is generally employed only for finishing the bores of special engines, e.g. those used for racing and competition purposes.

The method consists in fitting the worn cylinder with a dummy metal piston or " lap," and in working this up and down whilst it is rotating into the cylinder, using a fine abrasive and oil. The metal used for the lap is lead, copper, or any similar soft metal in which the abrasive materials will become embedded. If the abrasive is satisfactorily held in the sliding lap, a grinding or abrasive action will result, and the harder metal (cast iron) of the cylinder will be worn away in time to a cylindrical shape. Fine carborundum powder of a special grade for lapping can be obtained from abrasives manufacturers.[1]

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[1] Those interested should consult the publication: *Lapping and Compounds* (Carborundum Co., Ltd., Trafford Park, Manchester).

Fig. 444 shows a useful arrangement for lapping worn cylinders, made from an old piston of suitable diameter. The piston is sawn diametrically into two equal parts and a piece of sheet-metal strip, bent to a kind of "hair-pin" shape, is inserted between the gudgeon-pin bosses as shown. The outward spring of the two ends of this metal strip is arranged to keep the piston halves pressed laterally against the walls of the cylinder, but it is an advantage to be able to regulate this pressure by means of the set-screw shown on the left-hand side of the strip; the latter is drilled and tapped to take the set-screw in question.

A suitable metal, or wooden, handle passing through the lower part of the metal strip—bent in a loop for this purpose—completes the tool.

It is best to use an aluminium piston for this type of cylinder lap, as it has a much longer life than the softer metals. The lap should constantly be rotated as it is worked up and down the cylinder bore.

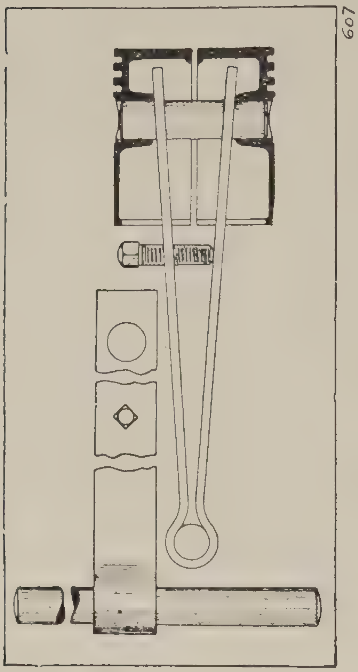

Fig. 444.—Showing Method of using an Old Piston as a Cylinder-lapping Tool.

Cylinder Grinding

There is little doubt that the grinding method of truing cylinders is the best one for all general purposes. Cylinders thus finished possess a cleaner and much smoother surface than those which have been rebored or reamed; moreover, there is no abrasive left in the metal. The grinding operation is also much quicker than any other.

In this method a small grinding wheel, attached rigidly to a stiff spindle, is rotated at a high speed and is slowly fed into the cylinder to be trued in an axial direction. The hard, vitreous abrasive wheel grinds off the metal very efficiently, and the depth of metal removed can be regulated to a high degree of accuracy; it is possible to remove only ·001 in. with a single cut, and less with a finishing or "middle" cut.

There are two methods of grinding automobile cylinders, namely:

(1) That in which the cylinder block is held rigidly to the table of the machine. The grinding wheel is of smaller diameter than the cylinder bore. The axis of the grinding spindle is given a slow eccentric motion, so that the grinding wheel can cut a larger bore than its own diameter. An automatic feed is provided for this eccentric movement, and the degree of eccentricity can be set to extremely fine limits in order to regulate the depth of grind.

(2) That in which the cylinder block is held to the face plate of a lathe,

REGRINDING BORES OF A SIX-CYLINDER CAR ENGINE ON CHURCHILL CYLINDER-REGRINDING MACHINE.

whilst the grinding spindle is carried on a bracket fixed to a slide rest on the lathe bed (Fig. 445). In this case the grinding spindle is driven quite separately from the lathe, either by means of an electric motor or by belt. The wheel is driven at a high speed, whilst the cylinder is rotated very slowly. The grinding attachments of this type are relatively inexpensive, and enable an ordinary heavy lathe, milling, or boring machine to be used. We shall describe these attachments first, and follow on with an account of one or two typical grinding machines. In the latter respect, these machines are much more convenient, more accurate, and very much quicker to set up the work with, but being expensive, a relatively large output of grinding work is necessary to justify their purchase.

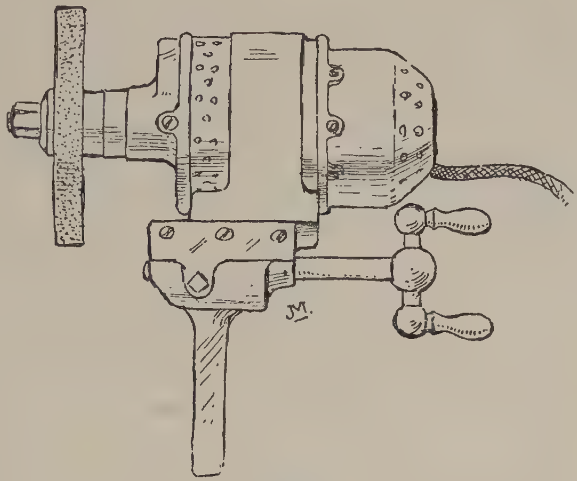
Fig. 445.—A Lathe Tool-post Type of Electric-motor Grinder.

Fig. 446 illustrates the "Fortuna"[1] internal-grinding spindle which can be fitted to any lathe or grinding machine. It has an accurately constructed ball-bearing spindle, running in well-lubricated bearings, capable of working continuously at speeds up to 40,000 r.p.m. The sizes of emery wheel range from $\frac{3}{16}$ in. up to 3 in.; the latter wheel can rotate up to a maximum speed of 10,000 r.p.m. It should be added that these spindles rotate at their high speeds without vibration and with no appreciable increase of temperature.

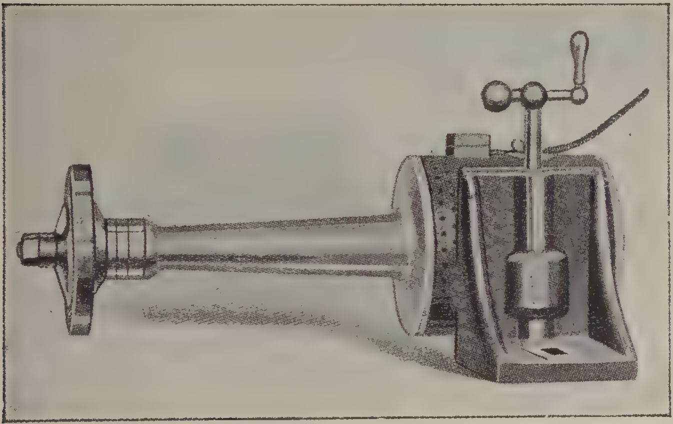
Fig. 446.—The "Fortuna" Cylinder-grinding Lathe Attachment.

The other class of grinding machine is best illustrated by the following account of one well-designed grinding machine, namely that made by the Heald Machine Company, Worcester, Massachusetts. This large firm has specialised in the design and manufacture of grinding plant, and more particularly in automobile cylinder, piston, and ring machines.

[1] The New Fortuna Machine Co., Bristol.

Fig. 447 illustrates the No. 55 Model Heald grinding machine—a model which is used to a large extent for automobile work. The various items of importance are indicated by the lettering and guidance lines on the photographic reproduction. The machine is of massive and, therefore, rigid construction, with sufficiently wide ways on the knee and tables to give support to six- and eight-cylinder blocks. It will accommodate all sizes of cylinders, there being 2½-in. vertical adjustment on all holes and 24-in. horizontal movement. The distance between the centre of the spindle and the table top is 7 to 9½ in. The travel of the main table is automatic, reversing automatically at any point desired. Two speeds are instantly obtainable by the movement of a knob on the front of the machine. The grinding-wheel spindle is hardened, ground, and runs in a solid taper bronze bearing at the wheel end, with a self-aligning ball bearing at the pulley end; the bronze bearing has provision for taking up wear. The standard arm will grind holes from 2⅜-in. diameter and larger by 11 in. long, and also holes 3-in. diameter and larger by 18 in. long. The standard grinding wheels are 2½- to 3-in. and 3½-in. diameter.

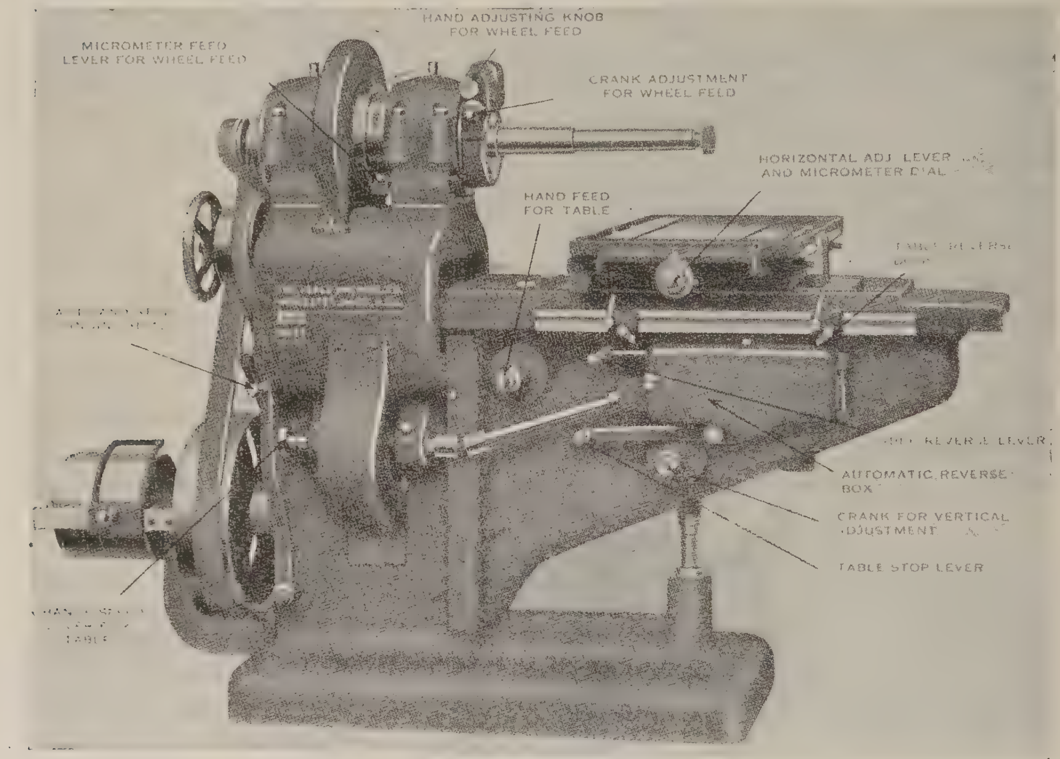
HAND ADJUSTING KNOB FOR WHEEL FEED
MICROMETER FEED LEVER FOR WHEEL FEED
CRANK ADJUSTMENT FOR WHEEL FEED
HORIZONTAL ADJ LEVER AND MICROMETER DIAL
HAND FEED FOR TABLE
REVERSE LEVER
AUTOMATIC REVERSE BOX
CRANK FOR VERTICAL ADJUSTMENT
TABLE STOP LEVER
TABLE

Fig. 447.—A Well-designed Cylinder-grinding Machine.

The speed of these wheels is 4,950 to 5,650 surface feet per minute. Micrometer dials are provided for horizontal and vertical adjustments. The table top measures 55¾ in. long by 16 in. wide.

Fig. 448 illustrates the arrangement of the grinding-wheel spindle and the feed mechanism for regulating the diameter of the grind or the radial feed of the wheel. The graduated dial enables the feed to be set very accurately, and, in the case of a number of cylinders in the same block, each can be ground to the same dial reading, and therefore to the same internal diameter. The use of this dial indicator saves the mechanic the time and trouble of frequent callipering.

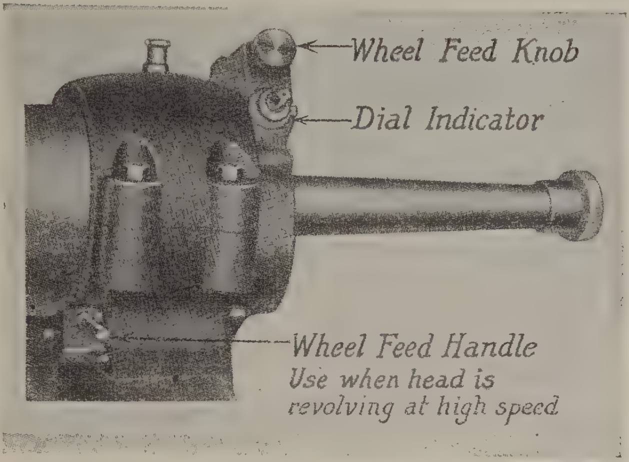

Fig. 448.—The Grinding-wheel Spindle and its Adjustments.

Mounting the Block

Use the bed and back edge of the table for alignment purposes. The wheel should be centred midway along the cylinder bore. Where many cylinder blocks of the same type have to be ground, a special jig should be rigged up to facilitate the rapid alignment of the bores. Fig. 449 illustrates a satisfactory design of jig for this purpose, and one which will locate and hold cylinder blocks of various sizes. The slotted bars, A, will allow for vertical adjustment for different-sized cylinders. To locate a cylinder so that the centre of the holes will be the correct height for the wheel to enter, measure the hole to be ground and move the top bar so that the locating

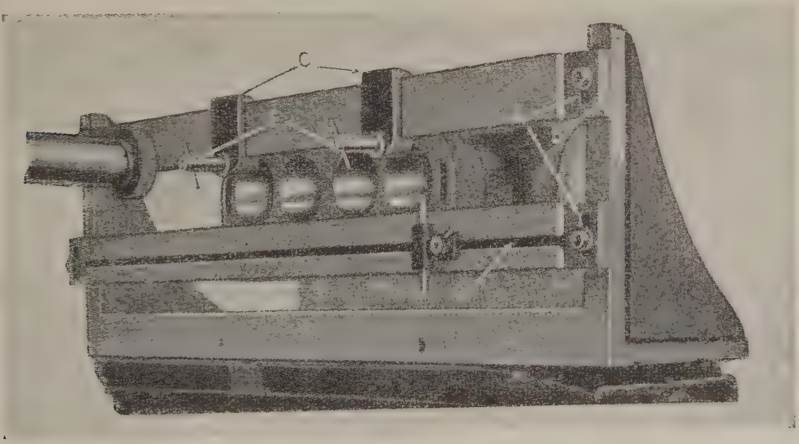

Fig. 449.—Method of setting up Cylinder Block.
A—Adjustable Cross-bar Slots. B—Locating Mark. C—Cylinder Clamps.
F—Clamping Screws. G—Bolt Slot.

mark will register on the scale the size of the hole as at B. Clamp the bar in this position, and slide the locating brackets, C, along the bar until the rods, F, are about the same distance apart as the two end holes; lift the block up on the rods and strap in place; remove the rods from the holes and slide the brackets out of the way for grinding. The track, G, on the lower bar enables the operator to move the truing diamond along to the hole he is working on. After the wheel is trued it can be easily moved out of the way.

The Churchill Cylinder-grinding Machine

A range of well-designed machines has been made available in this country by the Churchill Machine Tool Co., of Manchester. A particular model likely to interest motor engineers is that shown in Fig. 450. This machine, which is the smallest of six, has a capacity of 10 in. diameter by 18 in. in length; the largest has a capacity of 40 in. diameter by 120 in. in length. The work is bolted to the table shown on the left, and it can be fed across in relation to the grinding wheel which is shown mounted on the spindle near the centre of the illustration. The machine operates on the planetary principle, the grinding wheel moving in a circular

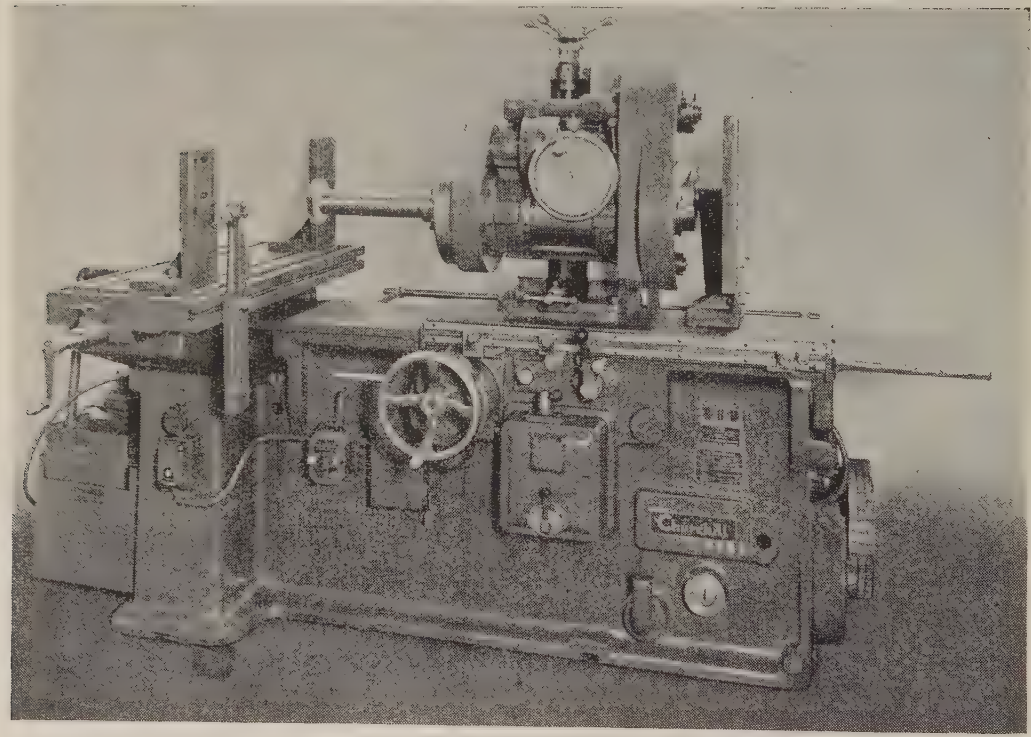

Fig. 450.—The Churchill Cylinder-grinding Machine.

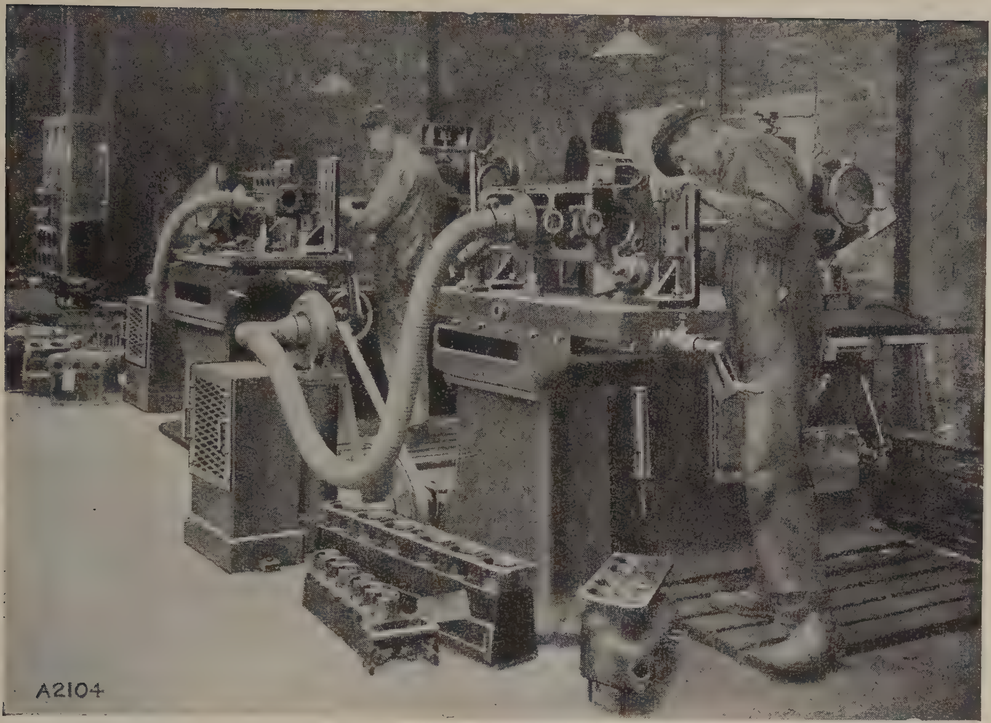

Fig. 451.—Two of a Battery of Ten Churchill Machines employed by a firm of engine overhaul specialists. The Dust-extraction Device is shown in each case.

track, or path, whilst it is rotated at a high speed on its own axis. The work table is mounted in a rigid manner, for it is stationary during the grinding and supported on a bed reaching direct to the floor. The hand-operated cross-movement is fitted with a micrometer dial which enables very accurate cross-adjustment between the bores. The traverse of the grinding wheel is by movement of the carriage on which the cylinder head is mounted (Figs. 450 and 452). The cylinder and ram type of hydraulic mechanism provides an infinite range of traverse speeds, the slowest being used for wheel trying. The maximum speed is 15 ft. per

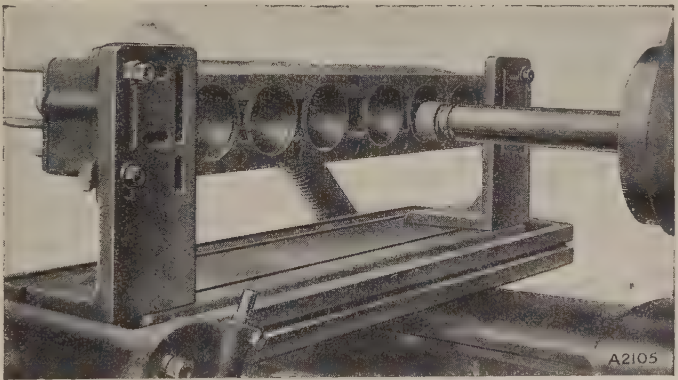

Fig. 452.—Showing how the Cylinder Block is mounted on Churchill Machine. Cylinders of various sizes can readily be fitted.

minute. Feed is applied by increasing the eccentricity of the grinding-wheel spindle with the main spindle, the adjustment being very sensitive and made by a hand wheel fitted with a dead stop. The grinding head is adjustable on a vertical column secured to the traversing carriage, and can be clamped in any position. The internal-grinding spindles can be changed very quickly, there being a wide range of interchangeable spindles available. This machine is self-contained and can be driven either by motor or belt; a special dust-removing apparatus can also be provided. This apparatus, fitted with large-diameter flexible pipes, is shown in Fig. 451.

Cylinder-grinding Notes

(1) Too great a " cut " should not be attempted on a grinding machine. It will not remove big turnings or chips like a lathe. On the other hand, a fine feed will remove the surplus material very rapidly.

As a guide to the amount of metal to take off in roughing out and also in finishing, we may consider the following case, namely, the removal of ·015 in. of metal from a cylinder. Having ascertained that the wheel is trued up, use the slowest speed of the table with the fastest speed of the eccentric, and take out ·004 in. for the first feed in, and ·002 in. when coming out. At the second feed in take ·001 in., and coming out ·002 in. At the third feed in take ·002 in., and coming out ·001 in. Finally let the wheel go in the fourth time with *no feed at all*; this will give a round, smooth bore.

(2) The right kind of grinding wheel should be used to suit the nature of the metal. Special compositions are used in the case of grinding wheels for very hard cast iron, for medium, and for soft cast iron; also for steel and aluminium.

(3) It is important to use the correct grinding speed, and the rear-shaft speed should be checked at intervals. A 2½- to 3-in. wheel should run at 6,950 r.p.m.; a 3½- to 4-in. wheel at 5,930 r.p.m.

(4) The amount of wear on a wheel is extremely small. Thus when taking ·010 in. each from four cylinders the wear will not exceed ·0005 in.

(5) Great care is necessary in lining up the cylinder to be ground.

(6) The grinding wheel should be trued occasionally with a black diamond mounted in a holder for this purpose. In the Heald machine a diamond mounted in a tool is supplied as part of the equipment. Light cuts only should be taken in each direction.

(7) *Dry grinding* is now used exclusively. Water on the surface being ground will not give a good finish.

(8) Do not allow the cylinder being ground to get too hot; it is best to allow it to cool after the roughing grinds, and before the final grind.

(9) An exhaust fan should be used to remove the grinding dust and particles.

(10) To obtain a good fine polish finish after grinding, use a roller

tool, as shown in Fig. 453. The 4½-in. diameter roller shown is mounted on ball bearings and rotates by friction action on the cylinder wall. It is of heat-treated alloy steel, giving a glass-hard surface, which should be burnish-finished. The roller dimensions shown must, of course, be reduced for ordinary automobile cylinders of 2½ in. to 3½ in.

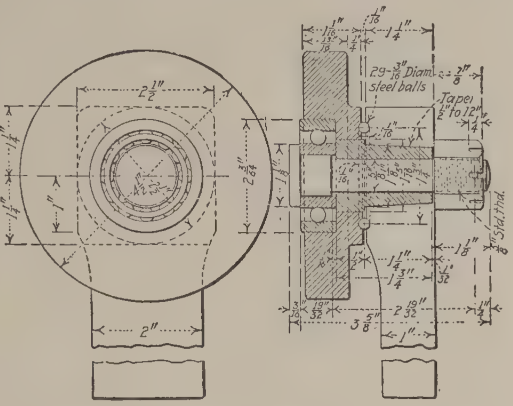

Fig. 453.—A Suitable Design of Cylinder and Crankshaft Polishing Wheel.

The Honing Method

Honing is a special application of the abrasive or grinding method, but instead of using a high-speed grinding wheel, a number of rectangular-section abrasive stones are employed. These stones are arranged with their longer sides parallel to the cylinder axis, in a radial manner, and internal springs are employed to press the stones uniformly against the cylinder wall. The honing unit is provided with an accurate method of adjusting the stones radially, so as to control the amount of cut.

The unit is rotated by a machine or motor drive at a much lower speed than for ordinary grinding, and whilst rotating and exerting a light pressure against the cylinder wall it is moved slowly up and down the bore; this is known as a *stroking action*. Fig. 455 shows a typical stroking mechanism of the hand-operated type.

The earlier designs of cylinder hones, which were of a more flexible character, usually followed the contour of the worn cylinder, and therefore did not true the bore properly, so that this type of hone gave satisfactory results only when the cylinder had been trued by reboring, reaming, or grinding, and its main purpose was to remove the cutter, reamer, or grinding " ridges," thus leaving a very smooth surface.

The modern cylinder hone has relatively long stones which pass right through the bore, being located by the unworn ridge at the top or bottom of the barrel, so that the hone will actually restore the worn bore to the truly cylindrical condition and in doing so give the surface a fine finish. Usually a roughing hone is employed where any appreciable amount of metal has to be removed, and a finer grade of stone for finishing purposes.

Usually the honing is done dry during roughing operations, when metal can be removed at a rate of ·002–·004 in. per minute from the average car-engine cylinder. A final accuracy of ·0005–·001 in. can be obtained with modern portable honing machines used on the cylinder block in the chassis. In the Ammco hone the problem of dust dispersal is taken care of by the self-lubricating principle, the buffing guides being impregnated with a dry lubricant. It is claimed that no suction device is necessary for getting rid of the abrasive and metal particles.

In most hones the number of stones used varies in the different makes of apparatus, some having four, others five, and some six stones. These devices are usually adjustable in range from about $2\frac{1}{2}$ in. to $5\frac{1}{2}$ in. so that they can be used for a wide range of cylinder sizes.

They are operated by electric drilling machines of the usual portable type, and usually rotate at 400 to 700 r.p.m. A $\frac{1}{2}$-in. to $\frac{3}{4}$-in. electric drill is usually employed. A number of different grades of stone are used, including coarse varieties for roughing, medium grades for ordinary truing up, and fine grades for finishing.

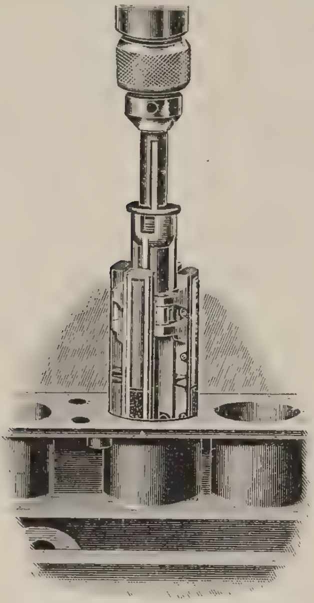

Fig. 454.—A Cvlinder Hone in Operation.

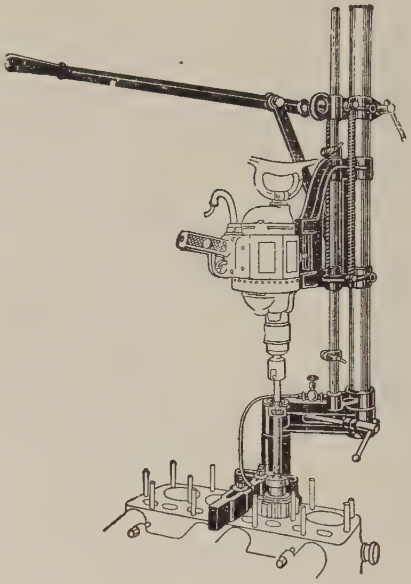

Fig. 455.—Showing how the Cylinder Hone is operated by an Electric Drilling Machine (Ammco).

For the roughing operations the stones are generally used *dry*, but for finishing they are used wet, paraffin being used for this purpose.

The amount of " cut " which can be given depends upon the size and condition of the cylinder. Most cylinder hones can be altered in diameter by as little as $\frac{1}{1000}$ in. at a time and, after roughing, cuts of $\frac{1}{1000}$ to $\frac{4}{1000}$ in. are usually given.

Honing Data

When using cylinder hones the speed of rotation of the hone depends upon its outside diameter and the type of honing stone used; also upon the amount of cylinder metal to be removed. In a typical case of cylinders being finished honed on a multiple-spindle machine the diameter of the cylinder was 3 in. and the speed of the hone 275 r.p.m. The reciprocating speed of the hone was 40 strokes per minute. The amount of material removed varies from ·0005 in. to ·0015 in.

In another instance the cylinders were first reamed true and from ·004 to ·005 in. then removed with the hone. For a 3½-in. bore the speed of hone was 250 r.p.m. with 50 strokes per minute. The outward pressure of the stones was 75 to 100 lb.

The length of the honing stones was about 20 per cent. greater than the cylinder, to avoid "barrel" effects when honing.

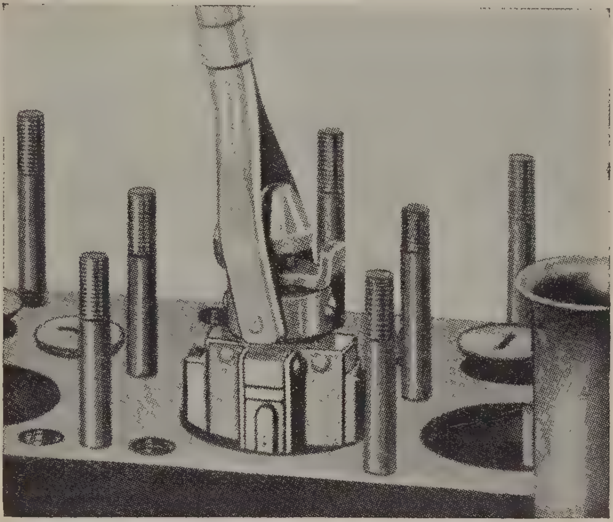

Fig. 456.—The Delapena Cylinder Hone.

The Delapena Cylinder Hone

The Delapena honing device[1] is based upon the dry-grinding principle, using a special design of honing unit in conjunction with a dust extractor. It can be used on the engine *in situ* if desired (Fig. 456).

The diametrical and longitudinal accuracy can be maintained to within ·005 in., with correct alignment between the manufacturers' centre lines of bores and crankshaft. The stones employed produce a mirror-like finish with which, it is claimed, no running-in of the engine is necessary.

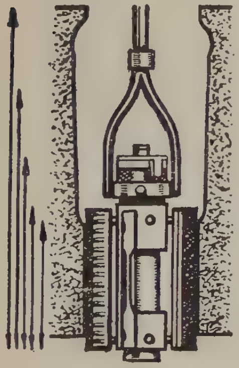

Fig. 457.—Method of using the Delapena Cylinder Hone.

The hone is *located from the bottom end* of the cylinder, i.e. where the cylinder wear is negligible as a rule, and is not affected by a bent connecting rod. Fig. 457 illustrates the method, and shows a cross-sectional view of a worn cylinder with the surface irregularities much exaggerated; the shaded section shows the metal to be removed. The arrows indicate how the operator starts honing the cylinder with short up-and-down strokes in the bottom part of the cylinder, lengthening the stroke as the metal is removed, and finally going through the complete bore by ½–¾ in.

The hone used has suitable guides to ensure cylindrical grinding, and both the stones and guides can be changed from the roughing to finishing series without tools, screws, carriers, or wedges in about half a minute. Twin guide blocks keep the hone centred in the cylinder.

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[1] Delapena. Ltd., Cheltenham.

The roughing stones will remove from ·002 in. to ·004 in. of cylinder metal per minute. The hones have a range to cover all motor-vehicle cylinder sizes. The hone, which has a universal joint at its driving end, is operated by means of a portable electric drill, as illustrated in the plate facing this page. The drill is suspended from an overhead support, the base of which is bolted to the cylinder block by means of a long helical spring.

A beam-pattern stroking stand is also available. This carries the electric-motor drive, a live drive shaft, and right-angle gear to drive the hone shaft; there is no fatigue experienced by the operator when using this stroking stand.

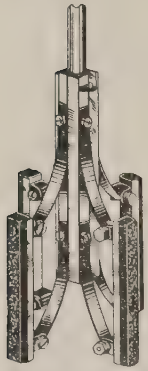


Fig. 458.—The Ammco Hone.

Cylinder Surfacing Hone

The Ammco cylinder surfacing hone shown in Fig. 458 has its own eight internal springs which provide automatic expansion and obviate the use of adjusting heads. It is designed for removing the tool feed marks left by the boring-bar cutter, and it will produce a fine surface finish in less than one minute. The hone is also useful for removing the shiny glazed surface of the worn cylinder when fitting replacement piston rings. Very little surface metal is removed, but the hone leaves practically a mirror finish.

The Ammco Self-lubricating Hone

This honing equipment comprises a pair of honing stones with their holders and a pair of guides, which are expanded to any maximum diameter within the range of the model, e.g. $2\frac{1}{2}$–$3\frac{5}{16}$ in. for the No. 388 size, and $3\frac{5}{16}$–$4\frac{1}{8}$ in. in the next size. The buffing guides are impregnated with a solid lubricant which controls the abrasive dust that otherwise would impregnate the atmosphere around the hone. The unit has a micrometer screw adjustment device and universal joint coupling for the drive. The latter is operated by a portable electric drill of $\frac{1}{2}$-in. diameter capacity. The normal honing is done with the honing stones supplied, whilst the final polishing process is effected by interchanging

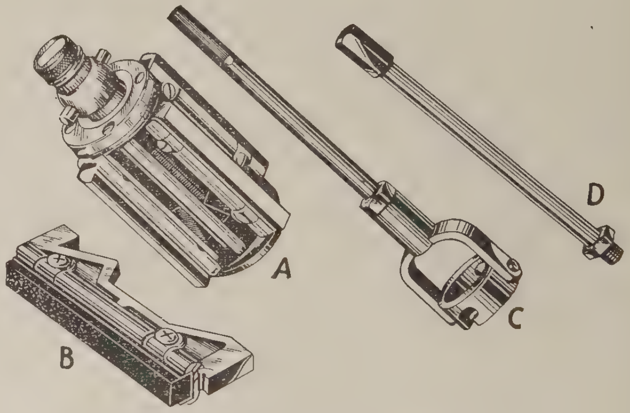
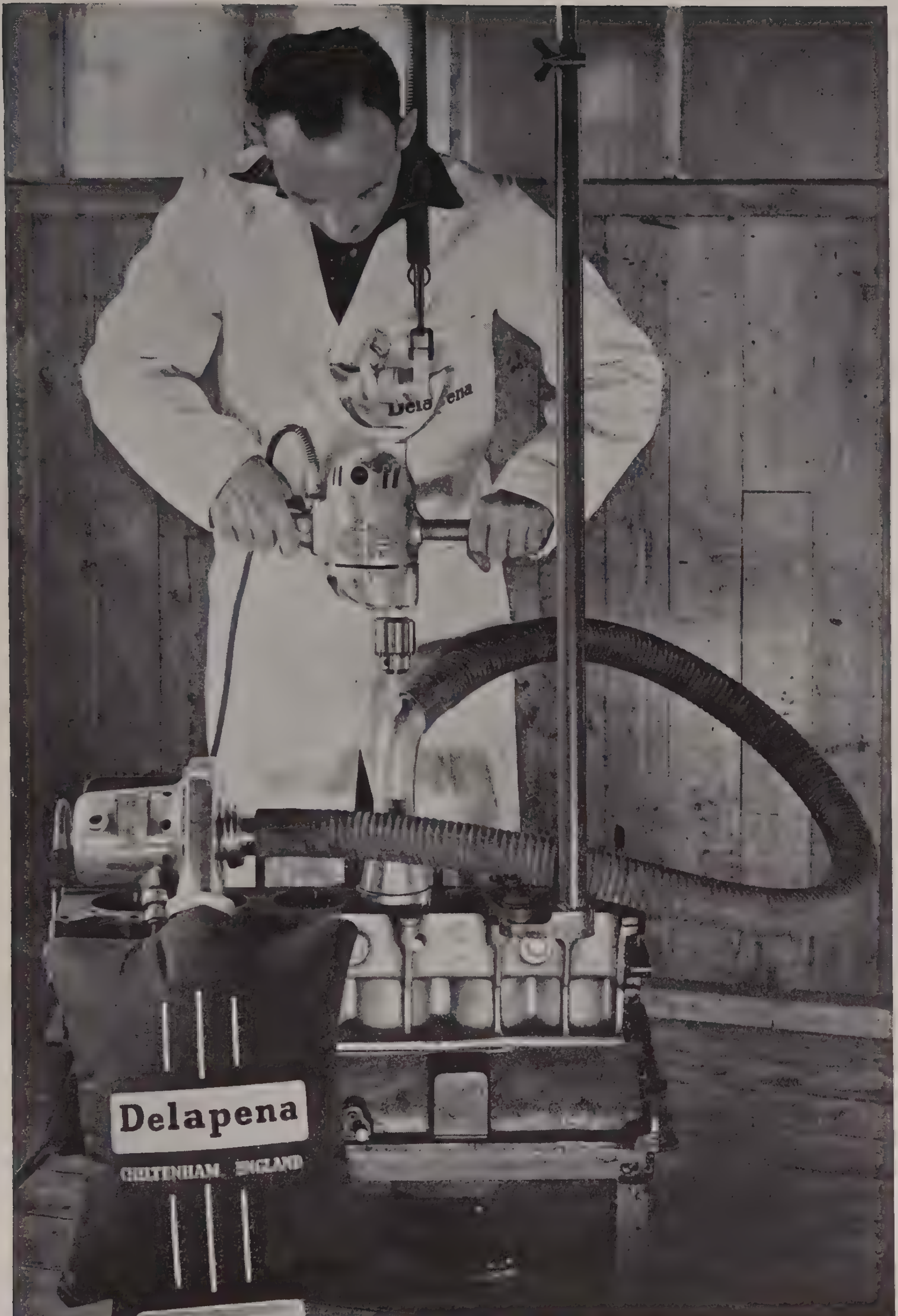


Fig. 459.—The Ammco Self-lubricating Hone.
A—Complete Hone Assembly. B—Honing Stone and Holder. C—Universal Joint Drive. D—Extension Drive Rod.



THE DELAPENA CYLINDER-HONING MACHINE, WITH DUST EXTRACTOR IN OPERATION.

these stones with a pair of burnishing hones, which produce a mirror-like finish.

Fig. 459 shows the complete hone and its accessories. The hone guides, it should be noted, have inclined faces which engage with a wedge expanding device in the body of the hone.

A Polishing and Burnishing Machine

Cylinders that have been reamed, ground, bored, or rough honed can be given a high degree of surface finish by means of the Buma machine illustrated in Fig. 460. The complete unit comprises the mounting for securing it to the cylinder block, the honing device, sliding keyed shaft, and stroking handle. There is also an adjustable collar for limiting the stroking depth, and an adjustable device operated by a milled hand wheel for expanding the hones. The honing unit is driven from a $\frac{1}{4}$-h.p. electric motor housed in the mounting.

The machine will remove from ·00025 in. to ·0005 in. of metal from the surface of the machined cylinder; this is sufficient to take out the fine machining marks. The hand wheel shown at the top of the hone operating shaft is first used to contract the hones to enable the unit to be inserted in the cylinder. It is then rotated to expand the hones to just touch the cylinder wall. Finally, it is moved in the same direction by one graduation in order to give the correct honing pressure and cut. After honing with this device, the hones are again contracted and raised, and a piece of soft cloth is placed across the bore. When the device is lowered and the hones expanded, the cloth is gripped between the hones and cylinder wall. The machine is started and the hone then run up and down a few times in order to complete the polishing operation.

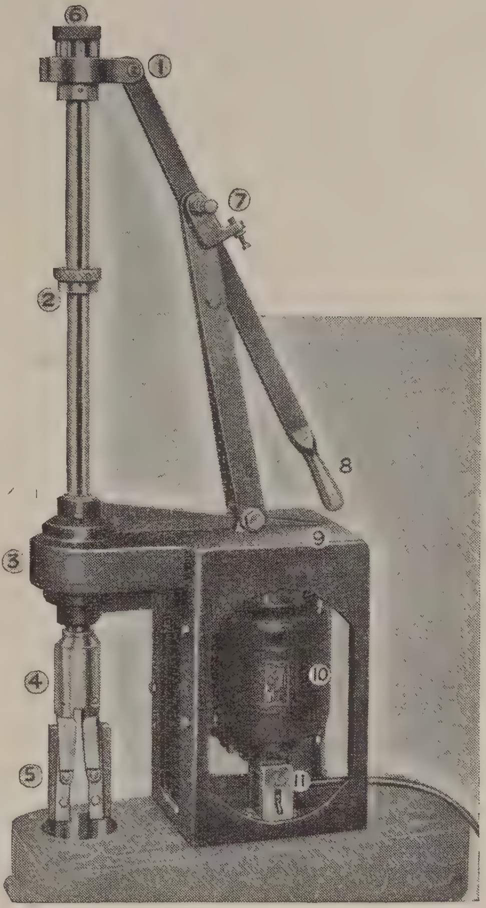


Fig. 460.—The Buma Polishing and Burnishing Machine.

1, Stroking-lever Hinge. 2, Sliding Keyed Shaft. 3, Shaft-bearing Housing. 4, Hone Drive Unit. 5, Hone. 6, Hone Adjuster. 7, Lever Hinge and Stop. 8, Lever Handle. 9, Stand. 10, Electric Motor. 11, Switch.

A Cylinder-honing Test

Some interesting tests witnessed during a demonstration in London consisted in taking a worn cylinder block and selecting a bore in which there was a bad ridge about 1·5 in. from the bottom, the top being oval to the extent of about 7·5 thousandths inch, and the bore had a mean taper from top to bottom of 13·7 thousandths inch. The following were the cylinder dimensions before and after using the "Hutto" honing device:

	In Crankshaft Direction.	*In Transverse Direction.*
Before grinding		
Top	3·1685 in.	3·161 in.
Bottom	3·151 in.	3·151 in.
After grinding		
Top	3·172 in.	3·172 in.
Bottom	3·1715 in.	3·1715 in.

It will be seen that the bore, after grinding, was truly cylindrical to within one-half of one-thousandth of an inch, parallel. The operation took twenty-four minutes, and the finished surface was excellent.

Larger Honing Machines

In the case of new cylinder blocks or of those which can be taken away from the chassis in large engine-servicing establishments, the larger types of honing machine enable the work to be executed more expeditiously and with a high degree of accuracy.

Being of a very rigid construction and fitted with a wide range of speeds, feeds, quick-stroke adjustments and other refinements, they are much more convenient to use and are, therefore, more economical in larger garages and engineering works, where a large number of cylinders has to be dealt with regularly. It is now well established that one of the best methods of machining cylinder barrels is to first bore them with a tungsten-carbide cutter head and then to remove the tool marks by honing in order to obtain a very fine surface finish.

A typical example of a modern motor-cylinder lapping machine is that of the Kitchen & Wade one shown in Fig. 461. This is made in three models, one of which has an hydraulic feed. The No. 2 model (Fig. 461), shown with its splash guards removed, is motor-driven with a range of six rotational speeds from 160 r.p.m. to 560 r.p.m., and cylinder honing sizes $\frac{3}{4}$–5 in. diameter or 2–6$\frac{1}{2}$ in. diameter and 70–280 r.p.m. as an alternative. The machine has six reciprocal or "stroking" speeds, namely three for rapid stock removal and three slow or "creeping" for mirror finishing purposes. Stroke changing is by self-locking screw, with an index reading from "0" to "Maximum" in an accessible position. Other features include ball bearings throughout, internal oil-pump lubrication, spindle having six solid splines, and a motor-driven paraffin pump and fittings for coolant purposes. Provision is made also for hand stroking in order to enable local honing to be carried out, as for tapered bore correction.

The splined spindle is hollow for bayonet shanks, and is provided with a quick-action chuck for rapidly connecting and disconnecting the honing units. This machine is much used in motor manufacturing and the larger engine-servicing establishments of large transport and motor works.

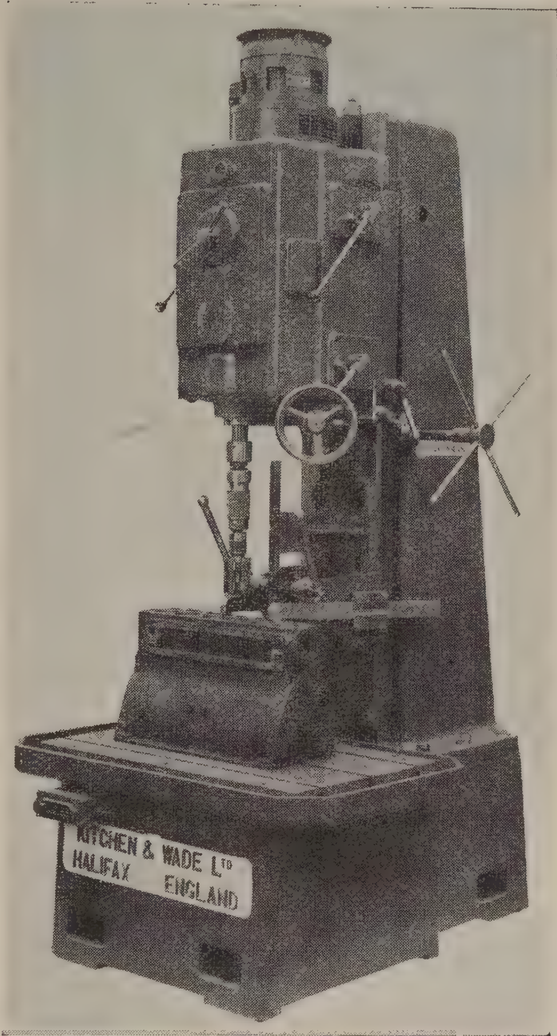


Fig. 461.—The Kitchen & Wade Machine or Production Honing.

Repairing Small Cracks in Water Jackets

The method of repairing cracked water jackets by the oxy-acetylene process, using cast-iron or bronze welding rods, is described in full in Volume III. In the case of small cracks, not exceeding 3 or 4 in., however, there are two other methods which can be used by the motor mechanic, namely, (1) *The Pegging Method* and (2) *The Soft Soldering Method.*

(1) *The Pegging Method.* In this method a small hole of, say, $\frac{3}{16}$ in. diameter is drilled through the jacket wall about $\frac{3}{8}$ in. beyond the extremity of the crack, at one end. The hole is tapped $\frac{1}{4}$ in. B.S.F. thread and a piece of brass or copper rod is screwed with the same thread so as to be a tight fit in the hole. It is sawn off close to the jacket wall after insertion. Next, another $\frac{3}{16}$-in. hole is drilled adjacent to the screwed plug and is then tapped so that it overlaps, slightly, the plug, as indicated in Fig. 462, and after tapping a second plug is screwed in and cut off. The procedure is repeated all the way along the crack and for a distance

of about $\frac{3}{8}$ in. beyond the other extremity. The tops of the plugs are then filed flush and the metal is cleaned for about $\frac{3}{8}$ in. all around the plugs and the whole area given a good coat of soft solder. This is not always necessary, however, if the plugs have been fitted correctly, in which case only a coating or two of cylinder-block enamel is required.

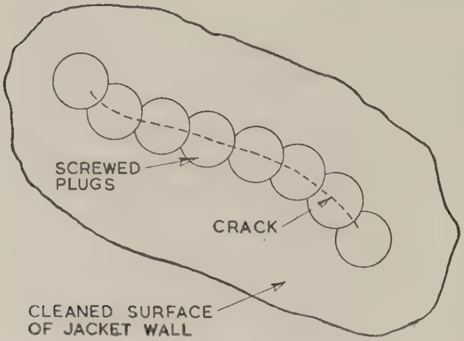


Fig. 462.—The Pegging Method of repairing Cylinder-jacket Cracks.

(2) *Soft Soldering Method.* The cylinder block should be removed from the chassis if the crack is on one of its vertical sides. Using a sharp triangular file, a groove is filed all along the crack and for about $\frac{1}{2}$ in. beyond each end so as to form a Vee for the solder to fill. The cast iron should be cleaned with a smooth file for a distance of about $\frac{3}{8}$ in. all around the crack so that a clean bright surface is obtained. Next, with the aid of a large crystal or crystals of copper sulphate (blue vitriol) dipped in water the whole of the cleaned surface is given a coat of copper merely by rubbing the wetted crystal on to the clean iron surface. The Vee-d portion should be similarly treated. This gives a good coppered surface which can readily be tinned, whereas cast iron is difficult to apply solder to. The copper surface must now be lightly cleaned with a piece of fine emery cloth. The block is heated gradually all over until when a stick of solder is rubbed on the surface it will just melt. Using a self-tinning solder or solder paste, proceed to tin the Vee-d and flat surface until a satisfactory coating is obtained. Then with the aid of a large soldering iron run plenty of solder into and above the surface of the Vee-d portion, afterwards building this up a little above the surface and over the copper area. The use of a soldering flux is recommended for this operation. It is better to build up the desired thickness of solder rather than to attempt to deposit it in one operation. Finally, when cold give a coating of cylinder paint or cellulose enamel.

Scored Motor Cylinders

It is occasionally found when dismantling cylinders of certain petrol engines that the gudgeon pin has worked loose, and in the course of time has gradually worn one or two grooves in the cylinder walls. If the gudgeon pin has been able to move in either axial direction, two grooves on opposite sides will have been worn, but if only free to move in one direction, of course there will only be one groove. The groove usually extends the length of the piston stroke, and in many cases it is sufficiently pronounced to cause a serious loss of compression, and it also allows the exploded gases to pass the piston during firing stroke. It is evident that the efficiency of the engine will be impaired; there will be a loss of power, and both fuel and oil consumption will increase. There will be a leakage of oil past the engine and into the combustion space, so that the latter will carbonise more quickly than is usually the case.

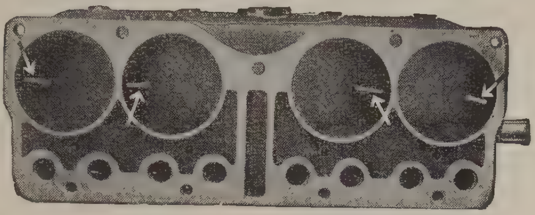


Fig. 463.—Showing Scored-cylinder Repairs.

It is fortunately possible to repair scored cylinders. The process in question consists in first scrupulously cleaning the scored parts of the cylinders, and then depositing a base metal by electrolytic means, afterwards adding a special alloy until the groove has been completely filled. The surplus metal is then removed by means of a special cylindrical scraper, similar in shape to the piston, which leaves the surface of the added metal perfectly cylindrical. This method of repair gives permanent results, for the metal employed does not melt, nor is it influenced by the exploded gases in any way. The compression-retaining qualities of the cylinder are thus restored.

The Lawrence process[1] of repairing scored cylinders consists of fusing silver-nickel alloy into the scores and regrinding the bore afterwards.

The Eagle process[2] (Fig. 464) utilises the method of dovetailing the scored part of the cylinder, and inserting in the groove thus formed a strip of copper alloy, which is then rolled into the dovetail so that it is immovable. This method, it will be observed, is quite mechanical, and involves no heating of the metal, so that there is no possibility of distorting the bore. The strength of the barrel must be reduced, however, due to the cut-away metal.

Another process, also of American origin, is that known as the "Bull Dog" one. This is in a way a combination of the other two methods, since the score is dovetailed and a metallic filler of high melting-point is fused into it. It is claimed that not only does the metal thus applied fill the score, but it also impregnates the pores adjacent to it, at the same time expanding as it cools.

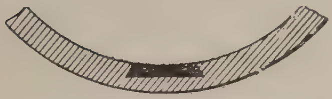


Fig. 464.—Illustrating the Eagle Process of repairing Scored Cylinders.

A good *practical method* which can be used in the garage workshop consists in using a hard solder, namely, one with a higher melting-point than the ordinary soft or tinman's solder; such solders are sold under various names.

The scores in the cylinder bore, (1) Fig. 465, must be cleaned thoroughly by scratching or scraping until quite bright. They should finally be washed with hydrochloric acid, and then with a zinc chloride flux made by dissolving as much zinc as possible in hydrochloric acid. A large size of soldering bit should be used to melt the solder; it should be tinned with hard solder and then heated almost to a dull redness. The cylinder should be pre-heated since this will greatly facilitate the work. The solder should be melted in the scores, and a surplus of metal left to ensure complete filling. The next operation is to scrape the surplus metal ((2), Fig. 465) away, so as to leave the hard solder flush with the surface as in (3), Fig. 465.

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[1] Lawrence & Co., 292 Halsey Street, Newark, N.J., U.S.A.
[2] Eagle Machine Co., Indianapolis, U.S.A.

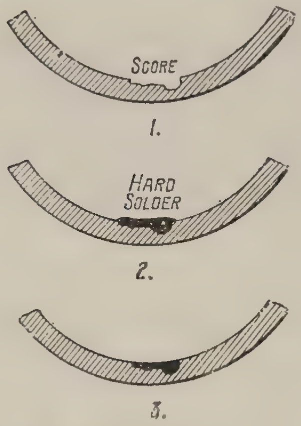

Fig. 465.—Showing how a Scored Cylinder can be repaired.

Evidently one cannot use the ordinary method of filing and scraping without a big risk of scratching or otherwise damaging the rest of the cylinder surface around the solder. One method is to make a dummy piston a little smaller than the cylinder bore, with an adjustable cutting tool. The piston is worked to and fro, and the tool adjusted until finally it is flush with the piston.

A useful tool which can be used with satisfactory results is that shown in Fig. 466. This consists of a scraper, A, of the same curvature as the cylinder, bolted to a tapered portion, B, to fit the drill-press spindle. The tool, A, is made wider than the scored groove, and the steel from which it is made is left soft so that whilst it will cut the solder it will be too soft to touch the cast iron of the cylinder walls. The tool is fitted to the drill press and is worked up and down, like a slotting-tool, the cylinder block being secured to the machine table. The feed lever of the drilling machine is used to give the reciprocating movement. The cutter is fed in until it just slides on the cylinder wall on each side of the score. In this way a perfectly good finish can be obtained, using ordinary workshop methods.

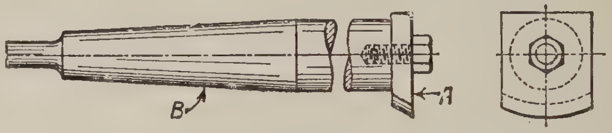

Fig. 466.—Tool for Truing repaired Cylinders.

Slight scores and marks on the cylinder walls are best removed by regrinding or honing, as their very shallow depths do not usually justify the use of the methods employed for deeper scores.

If the scores are deep ones, the advice of an expert should be sought, as the possibility of an ultimate failure by fracturing or distorting under the influence of the explosion pressure must be considered. *In serious cases* a welding repair, or the actual welding in of a new barrel, can easily be carried out by a specialist firm such as Messrs. Barimar, Ltd.

Cylinder Liners

In order to prolong the life of the automobile engine it is now becoming the practice—more particularly in the case of the large motor-car, and commercial engines—to design the cylinder blocks so that separate cylinder barrels, or liners, can be fitted.

It is also possible to fit cylinder liners of a special grade of alloy cast iron to ordinary cylinders, by first boring the existing cylinder to $\frac{1}{16}$ in. to $\frac{3}{16}$ in. larger in diameter, and after pressing the liners in place to hone the latter out to approximately the initial diameter of the cylinder.

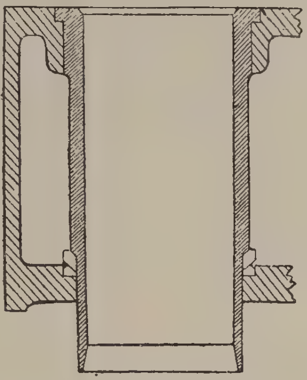
Fig. 467.—Wet-type Cylinder Liner.

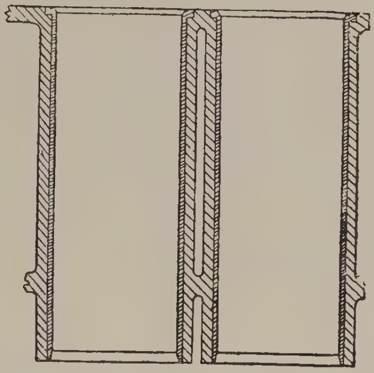
Fig. 468.—Dry-type Cylinder Liner.

The liners used for automobile engines are of two types, viz. the *Wet* and the *Dry* ones (Figs. 467 and 468). In the former case the outside of the liner forms the complete cylinder barrel and is in contact with the water of the water jacket, whereas in the latter case the liner fits inside another barrel forming part of the cylinder casting. The dry-type liners are used largely for repair work where the cylinder bores have become worn, as previously mentioned.

The advantages of using cylinder liners are as follows:

(1) The alloy irons used can be heat-treated, and give from three to four times the wearing life of ordinary cylinder cast irons.

(2) The use of liners enables standard sizes of pistons to be used at all times. It is not necessary, therefore, to carry stocks of oversize pistons for replacement purposes.

(3) No cylinder reboring operations are necessary; the old worn sleeve is pressed out and a new one inserted.

The only disadvantage that can be associated with liners is the higher initial cost of engines fitted with them; against this may be set the reduced servicing costs of the engines.

Cylinder liners in modern engines *are relatively thin.* Thus for cylinder bores of $2\frac{1}{4}$–3 in. the thickness of the liner usually lies between ·070 in. and ·085 in., i.e. a little over $\frac{1}{16}$ in. thick. For larger bores the thickness increases, e.g. for cylinders of 4–5 in. bore the thicknesses vary from ·120 in. to ·150 in.

The modern method of making cylinder liners is to select special grades of alloy cast iron, and to cast the latter into cylindrical form by a centrifugal casting process, whereby the molten metal is rotated rapidly in the mould. No sandmoulding or cores are therefore required and the metal, as cast, is dense and free from bubbles or other defects.

Most cylinder liners are of the alloy cast-iron centrifugally-cast type, either unhardened or heat-treated in order to bring out the maximum strength and wear properties. The most favoured cast iron for cylinder sleeves is that containing nickel and chromium.

The *method of heat-treatment* of a typical alloy iron of this class, e.g. Brico grade used for cylinder sleeves, consists in first heating the sleeves in an electric furnace to 830–860° C., pressing the sleeve through a special die into a bath of oil to avoid distortion and to reduce the amount for final grinding. The sleeve is then tempered in another furnace at 330–350° C. for a period dependent upon the volume of metal in the liner.

The heat-treatment process, it will be seen, is the work of expert firms, and for this reason should not be attempted in the motor works. A further reason is that the specialist firms supply new cylinder liners in all sizes to suit standard vehicle engines, the liners being sent in their heat-treated condition and to exact dimensions for fitting in the prepared cylinder bores.

Hardness of Cylinder Liners

Modern alloy-iron cylinder irons of the nickel-chrome class, when hardened, will give Brinell hardness numbers of 400–500, and they will not expand, shrink, or contract if properly fitted into the cylinder. When it is remembered that ordinary cylinder-block irons as used in most production car engines and some vehicle ones have Brinell hardnesses of only 180–200, it will be realised why the former alloy irons wear for very much longer periods before replacement becomes necessary.

Other Cylinder-liner Metals

The various metals used for cylinder liners include the hardenable nickel-chrome irons, martensitic and austenitic irons, " loded " cast irons, and Nitri-cast irons. Steels[1] are not used for automobile cylinder liners. Proprietary makes of liner cast irons that can be recommended include Brimol, Durocyl, Centrard, and Chromidium.

Some Liner-test Results

Apart from the general experience of commercial-vehicle owners who have confirmed the cylinder-liner manufacturer's claims of longer mileages, a number of tests have been carried out with the object of measuring the amounts of wear occurring over various road mileages.

The rate of wear of ordinary cast-iron or plain alloy-cast-iron cylinders, without liners usually lies between $\frac{1}{1000}$ in. per 1,500 miles of road service to $\frac{1}{1000}$ in. per 4,000 miles, according to the grade of iron and conditions of use.

With Centrard cylinder liners, made by Sheepbridge Stokes Co., Ltd., of Chesterfield, data obtained from road tests show that the maximum wear which occurs in such liners amounts to only $\frac{1}{1000}$ in. per 20,000 miles.

Tests made with Brimol liners, made by the British Piston Ring Co.,

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[1] Other than Nitralloy ones.

Ltd., of Coventry, prove that the maximum cylinder-bore wear is $\frac{1}{1000}$ in. for 12,000 to 19,000 miles of road service.

Under these circumstances, the cylinder liners in question will give at least 100,000 miles of useful service before replacement becomes necessary, i.e. about three to four times the life of ordinary cast-iron cylinder barrels.

Nitri-cast Iron and Nitralloy Cylinder Liners

Special Nitri-cast iron and Nitralloy liners are now used in certain makes of engines and also for fitting into cast-iron cylinders for reconditioning purposes.

For special liners, Nitri-cast iron is employed. This is a special alloy cast iron which, by means of a nitriding process, may be *case-hardened.* Liners produced in this material are case-hardened after being machine-finished by subjecting them to the action of anhydrous ammonia gas at a temperature of 500° C., the period depending upon the depth of case and hardness necessary. Nitri-cast iron contains about 1·5 per cent. of aluminium with about ·5 per cent. chromium. A period of ninety hours is required to give a penetration of ·03 in.

The Nitralloy liners are produced from a special grade steel less than 1 mm. thick, and are treated by the nitrogen-hardening process so as to yield a surface considerably harder than ordinary cast-iron steel. After the preparation of special jigs to ensure accuracy within very fine limits, they are inserted by hydraulic pressure into the cylinders, which have previously been bored out to receive them, and are finished in position to standard size. These extremely hard liners are less susceptible to wear than the ordinary cylinder wall, owing to their greater hardness and the high polish they acquire; moreover, the working friction is reduced and piston wear retarded. If at any time cylinder wear should manifest itself, it is a straightforward matter to extract the liner and insert a new one. In most cases it is not necessary to replace the pistons.

The nitrogen-hardening method, it will be seen, has many advantages over ordinary case-hardening, a big point being the comparatively low temperature of nitration, so that distortion is obviated. Further parts can be machined-finished before nitriding, after which they are ready for service, except for removing any slight surface faults. No quenching is required and there is no risk of hardening cracks developing. It is interesting to note that this casing resists the corrosive action of fresh or salt water, runs with less friction than ordinary steels, requires less lubrication, and minimises the risk of seizure.

Duralumin connecting rods can be run direct in nitralloy crank-pins without the use of white-metal linings.

Cylinder-liner Dimensions

The wet type of cylinder liner, which is used to a much smaller extent than the dry type, is made a simple push fit in the cylinder bore, since the water joint is made with the aid of rubber rings. The liner is therefore quite easy to fit and withdraw, although one or two simple precautions, referred to again later, must be observed.

The dry type of liner has to be made a driving, press, or interference fit in the cylinder block for two reasons, namely: (1) to prevent any movement in the block, which may have serious consequences; (2) to give good heat conduction through the block metal to the water in the jackets. If the contact between the liner and block metals is not a good one, the engine will tend to run hot and lose power.

When an engineering part is made a good press fit, i.e. an interference fit, the outside diameter of the part is *slightly larger* than the diameter of the hole. Thus for a hole of 2 in. diameter the shaft would be made about ·002–·003 in. larger than the hole, which should be 2 in. in diameter. Similarly, cylinder liners for cylinder-block bores of 2–3 in. should have outside diameters ·002–·004 in. larger than the cylinder bores.

In order to *obviate the making of calculations* for cylinder-bore dimensions when the cylinders are to be bored out to take liners, it is now usual for the manufacturers of liners to state in their catalogues *the exact sizes*, with the usual tolerances, to which the cylinders must be bored out, in order that the liners supplied will be an interference fit ; further, the liners will have internal bores to suit the standard size of piston, after slight honing of the liners when they have been inserted in the block. As a typical example, the British Piston Ring Co., Ltd., Coventry—a firm that makes a considerable range of cylinder liners—issues a comprehensive list of liner dimensions, typical examples of which are as follows:

Dimensions of Brico Cylinder Liners

Correct Engine Bore (Standard).			*Dimensions to Bore out Cylinder Block. (Tolerances: — ·0005 in. to — ·001 in.)*	
Inch.	*Millimetre.*	*Decimal (Inch) Equivalent.*	*Inch.*	*Decimal (Inch) Equivalent.*
—	55	2·165	$2\frac{5}{16}$	2·313
2½	—	2·500	$2\frac{21}{32}$	2·656
—	65	2·559	$2\frac{23}{32}$	2·719
2¾	—	2·750	$2\frac{29}{32}$	2·906
—	72	2·835	3	3·000
3	—	3·000	$3\frac{5}{32}$	3·156
—	78	3·071	$3\frac{7}{32}$	3·219
3½	—	3·500	$3\frac{21}{32}$	3·656
—	90	3·543	$3\frac{23}{32}$	3·719
4	—	4·000	$4\frac{3}{16}$	4·188
—	110	4·331	$4\frac{17}{32}$	4·531
4½	—	4·500	$4\frac{5}{8}$	4·625
—	115	4·528	$4\frac{3}{4}$	4·750
—	120	4·724	$4\frac{15}{16}$	4·938
5	—	5·000	$5\frac{7}{32}$	5·219
5½	—	5·500	$5\frac{23}{32}$	5·719

A special feature of the Brico cylinder liners is that the entering end (lower) of each liner is reduced slightly in diameter to assist in fitting. The actual *dimension of the entering end* is the exact diameter of the hole in the cylinder block that will enable *the rest of the liner to be the correct interference fit in the block.* Therefore it is necessary only to measure the entering end diameter with an outside micrometer calliper in order to ascertain the required diameter to which to bore the cylinder block.

In regard to cylinder-liner dimensions, Fig. 469 shows the Centrard cylinder liner, with the various sizes indicated by letters. The following are the fitting instructions for these liners:

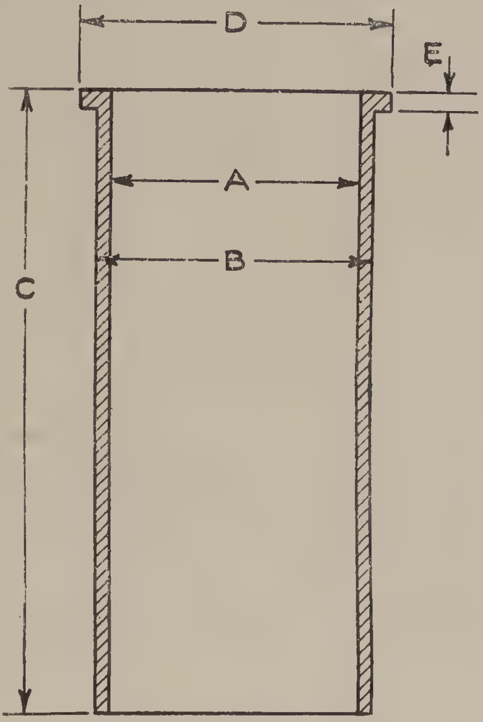


Fig. 469.—Dimensions of Liners.

(1) The outside diameter B of the flanged liners is ground slightly larger (by plus ·001 in. to ·0025 in.), according to the diameter. The flange D is ground (to D minus ·003 in. to minus ·005 in.).

The flange depth E is ground

$$\left\{\begin{matrix} \text{E plus } \cdot 000 \text{ in.} \\ \text{minus } \cdot 002 \text{ in.} \end{matrix}\right\}$$

(2) For Centrard (nitrogen-hardened) liners the bores A are provided with an allowance of ·001 in. to ·0035 in. for finishing after insertion of the liner.

(3) The preliminary boring operation of the block should finish at

$$\left\{\begin{matrix} \text{B plus } \cdot 0000 \text{ in.} \\ \text{minus } \cdot 0005 \text{ in.} \end{matrix}\right\}$$

(4) The recess in the cylinder block to receive the flange of the liner

should be bored to $\left\{\begin{matrix} \text{D plus } \cdot 001 \text{ in.} \\ \text{plus } \cdot 002 \text{ in.} \end{matrix}\right\}$

with the depth $\left\{\begin{matrix} \text{E plus } \cdot 0005 \text{ in.} \\ \text{minus } \cdot 0005 \text{ in.} \end{matrix}\right\}$

The liners are provided with a radius approximately $\frac{1}{32}$ in. under the flange and a radius or chamfer of approximately $\frac{1}{16}$ in. should be provided at the corresponding place in the cylinder block.

(5) Centrard liners are left unhardened in the bores for a length of 2 in. from the end opposite to the flange: this is to enable connecting-rod clearances and chamfer to be cut, if necessary, after fitment.

Fitting Liners to Ordinary Cylinders

When an ordinary non-sleeved cylinder block has been rebored twice, after long service, the cylinder walls may become too thin to permit a third rebore. It is therefore advisable, after the first rebore, to bore out the barrels so as to take cylinder liners. In some engines there is still sufficient metal, after the second rebore, to permit a further rebore to enable a cylinder liner to be fitted. The barrel should be bored to within about ·002–·003 in. of the size for the liner to be an interference fit, and then fine honed to the exact interference fit dimension.

Typical Examples of Liner Practice

The cylinder liners fitted to the Standard Vanguard engine are of the wet type, with a long bearing in the cylinder block at the lower end and a short flange at the upper one. The top flange is not of the usual circular shape, but is machined so as to have four flats mutually at right angles. These prevent the liners from turning about their axes. One advantage of this arrangement is that when cases of light wear occur and cause *piston knock*, an improvement can be effected by withdrawing the liner and rotating this through 90°, so as to employ an alternative pair of flats on the liner flange (Fig. 470). The dimensions of the new sleeve are given in Fig. 471, and this information will be found very useful when servicing Vanguard engines. Cylinder-sleeve retainers (Fig. 472) should be used to prevent relative movement of the liners. In addition to the danger of liner movements if retainers are not fitted, when the crankshaft is turned there is a possibility of these moving when the combustion head is broken, particularly when jointing compound has been used on both sides of the gasket.

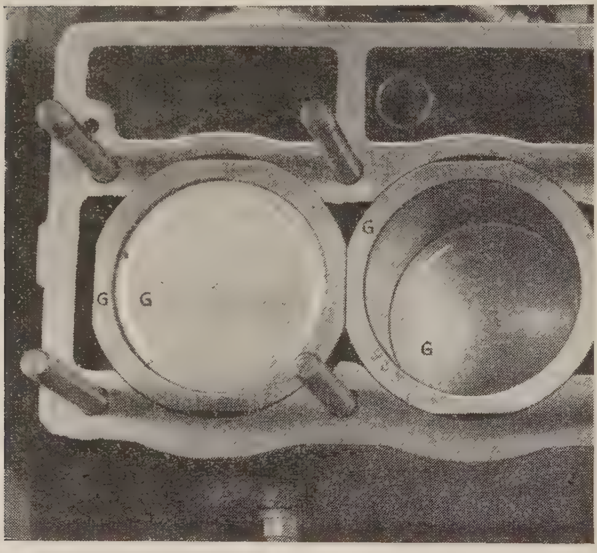
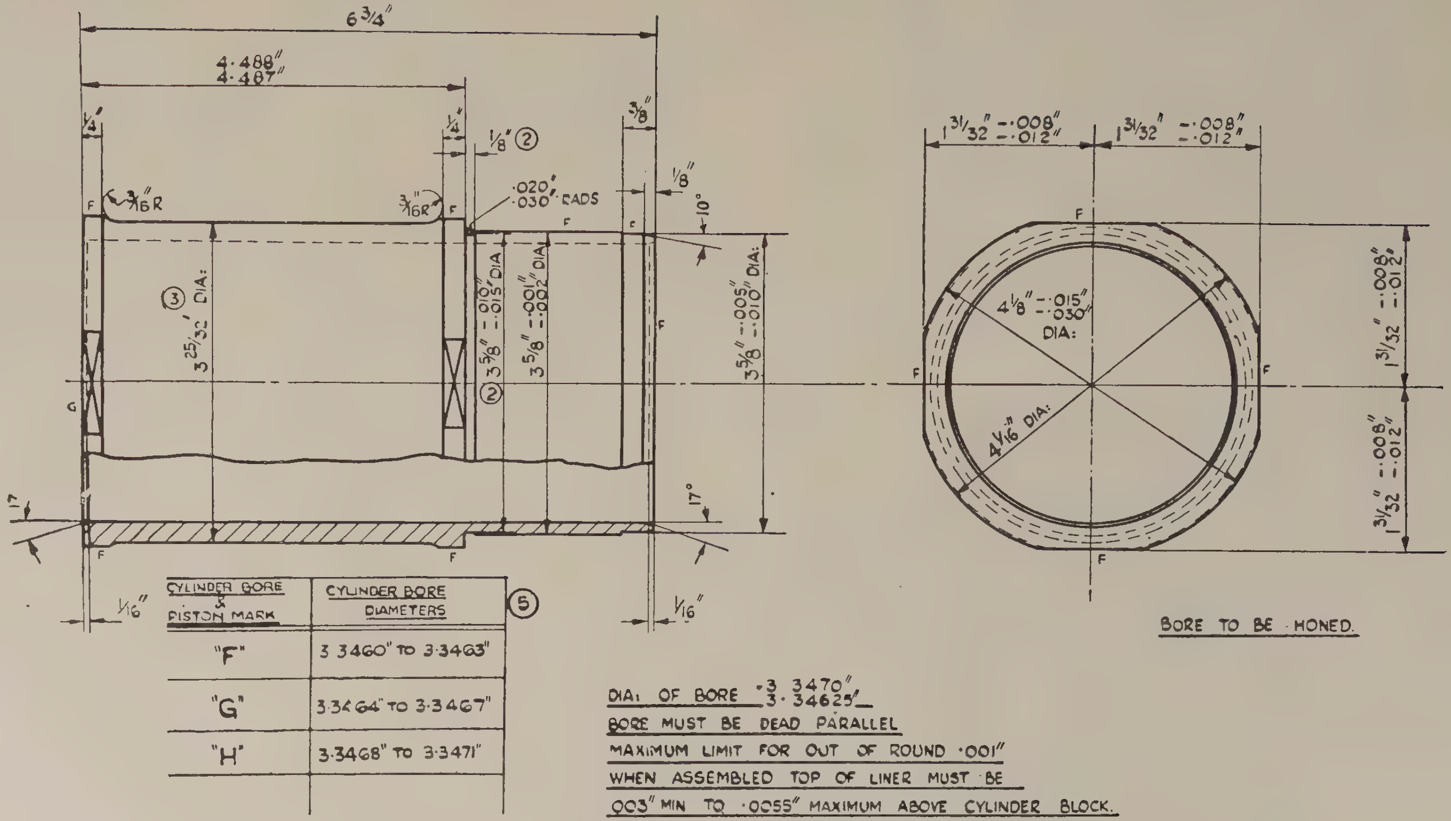


Fig. 470.—The Vanguard Cylinder Liners, showing Flats on Top Flanges and Marking G on Liners and Pistons.

It will be noted from the data given in Fig. 471 that when the cylinder liners are installed in the block the flanged face should stand proud of the cylinder-block face by ·003 in. (minimum) and ·0055 in. (maximum).

In regard to the cylinder-head gasket, information concerning this is given later in this chapter.



CYLINDER BORE & PISTON MARK	CYLINDER BORE DIAMETERS
"F"	3 3460" TO 3·3463"
"G"	3·3464" TO 3·3467"
"H"	3·3468" TO 3·3471"

DIA: OF BORE ·3 3470" / 3·34625"

BORE MUST BE DEAD PARALLEL

MAXIMUM LIMIT FOR OUT OF ROUND ·001"

WHEN ASSEMBLED TOP OF LINER MUST BE

·003" MIN TO ·0055" MAXIMUM ABOVE CYLINDER BLOCK.

Fig. 471.—Dimensions of Standard Vanguard Liner.

The cylinder liners of the Thornycroft Trusty engine are of the dry type. The method of removal and insertion of these liners requires the use of the special tools supplied for this purpose. *The procedure for removal* is illustrated at A in Fig. 473. The long stud, with its bottom spigot and nut in position, is passed upwards through the cylinder bore. Next, the spigot is fitted into the bottom of the liner and the tube placed over the top of the stud. The cap is then fitted to the top of the tube by passing it on to the stud. The thrust ball bearing and head nut are then placed in position, as shown. Before turning the head nut, make sure that the gear is firmly fixed, and that the points of contact are fully engaged. Then rotate the head nut, by means of a spanner, in a clockwise direction, thus drawing up the stud and with it the liner.

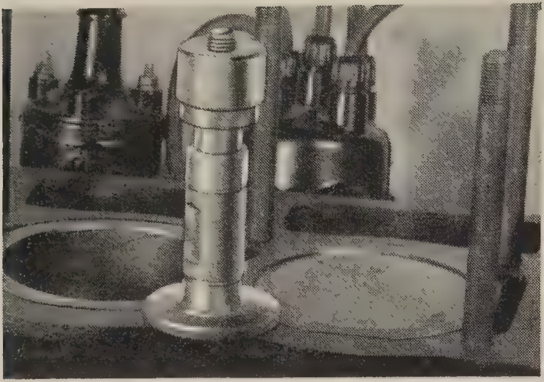


Fig. 472.—Cylinder-liner Retainer.

The *method of fitting a new liner* is illustrated at B and C in Fig. 473. Owing to the valve-clearance recesses in the tops of the liners for cylinders Nos. 1, 2, 4, and 5 being opposite hand to those for cylinders Nos. 3 and 6, two separate gears are required. Locating spigots fit into the valve-clearance recesses, and then positions in the two separate gears are reversed. Care must be taken to select the correct gear for the particular liner to be fitted and to ensure that each set is marked with the cylinder. Before inserting the new liner, clean the cylinder bore thoroughly, taking care not to scratch it.

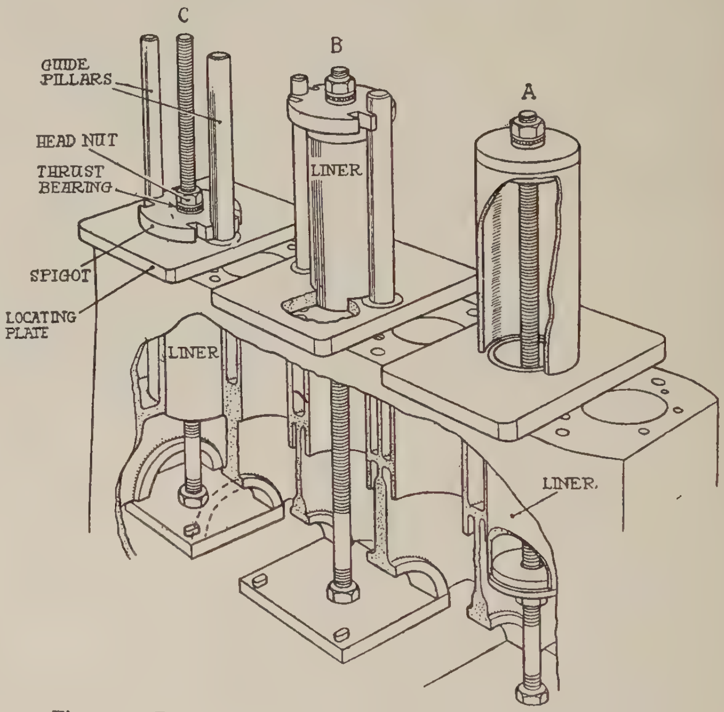


Fig. 473.—Removal and Insertion of Thornycroft Cylinder Liner.

Then apply a little acid-free lubricant, such as " Pressolene," to the outside of the liner and inside of the cylinder bore.

Fit up the gear for pressing in the liner as indicated in Fig. 473. Place in position the long stud, bottom plate, and nut. Fit the correct locating plate over the stud with the pin on the left-hand side of the engine, and locate the plate by means of the locating pin. The guide pillars must be fitted in the positions indicated in Fig. 473.

Place the new liner in position with the recesses upwards and to the left of the centre line of the engine, fitting the " lead-in " at the bottom of the liner squarely into the cylinder bore. Place the correct spigot in position in the top of the liner, making sure that the locating spigots are seating correctly in their respective recesses in the top of the liner. Fit the thrust bearing and head nut.

See that the gear is firmly fixed and that points of contact are fully engaged. With a square, check that the liner will enter the cylinder block squarely.

With a spanner, screw down the head nut, and so press the liner into the block.

During the insertion of the first inch or so the load must be released several times to allow the liner to correct any small misalignment. On no account must misalignment be corrected by tapping the liner or gear. Check for misalignment several times until the liner is well into the cylinder block.

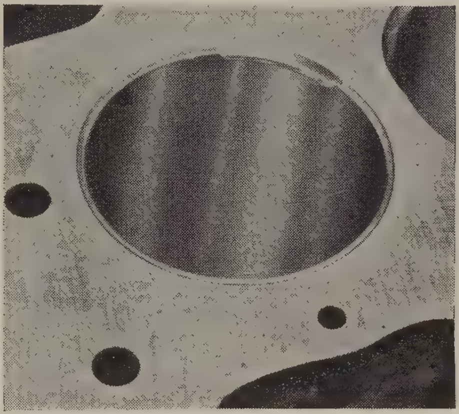


Fig. 474.—Bedford Engine Cylinder-liner Recess.

Press the liner home, flush with the top face of the cylinder block. The spigot will prevent the liner from being pressed in too far.

The liner bores will require honing after insertion; the exact diameter after honing must be arranged to suit the *selective fit* pistons allowing, of course, for the proper working clearances according to the manufacturers' schedule of fits and clearances.

Location of Liner Heads

From the examples of the Standard Vanguard and Thornycroft engine liners it will have been noted that these were fitted with the flanges or heads in a definite position in relation to the cylinder block (or piston). When the head of a liner has a recess, as in Fig. 473, this must be accurately positioned, and in this connection the manufacturer's instructions should be followed. In the example shown in Fig. 473, a worn cylinder block has been rebored to take liners, so that standard pistons are then used. The liners, when worn, can be rebored to accommodate pistons up to ·040 in. oversize.

Fitting Dry-type Cylinder Liners

Assuming that the cylinder-block barrels have been bored out, with the usual type of boring bar, to the interference fit dimensions within the tolerances or permissible limits, i.e. —·0005 in. to —·0010 in., it is necessary to examine the cylinder to ascertain whether there are slots at the lower end of the barrel for connecting-rod clearance. It is possible in some designs to machine out these slots *after the liner has been inserted*; the lower end of the liner is left unhardened for this purpose.

Otherwise it will be necessary to cut slots in the liner before it is inserted. The method recommended for Brico liners is to make the slots in the liners wider by $\frac{1}{32}$ in. than the width of the slot in the cylinder block. The slots should be marked out on the liner. Then a series of $\frac{1}{8}$-in. diameter holes should be drilled, as shown in Fig. 475. Next the sides of the slot are cut down with a hacksaw and the unwanted pieces gently removed. When inserting the liner make sure that the slots of the liner are in line with those of the cylinder barrel before pressing the liner into position. It should here be mentioned that it is *advisable to hone the cylinder barrel* to the final interference fit size rather than to use the boring cutter to finish the bore to size. A honed barrel gives the best finish for cylinder liners.

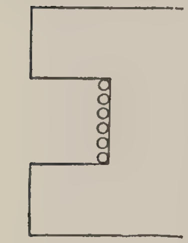


Fig. 475.—Making Slot in Cylinder Liner.

The liner is inserted into the cylinder block with the aid of a special liner insertion tool or by means of an hydraulic or screw press; these items are described more fully later.

Before forcing the liner into its bore it should be smeared with oil, soap, or medium non-acid grease. The inside of the block bore should also be treated in a similar manner. This ensures that no vibration or chatter of the liner will occur during insertion. The entering or "lead-in" end of the liner should be pushed squarely into the cylinder block before using the liner insertion tool or press. Assuming that an hydraulic press is used, the liner should then be inserted an inch or two and the pressure released. This will enable the liner to correct any misalignment; this procedure should be repeated two or three times, after which the liner may be pressed gradually home until it is flush with the top of the cylinder block. Under no circumstances should any part of the liner, after insertion, project above the machined face of the cylinder block; otherwise it will not allow a good joint to be made for the cylinder head when the gasket is in position, and blow-by will occur.

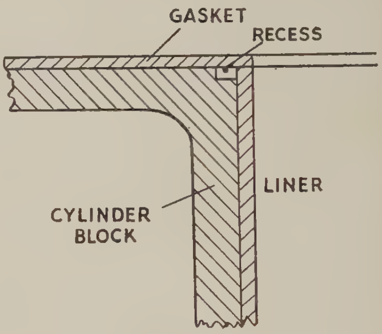


Fig. 476.—Using Plain instead of Flanged Liner.

When plain liners of the Brico or similar type are fitted to cylinders which have previously had flanged head liners, the small space at the top

(Fig. 476) is not a disadvantage, since it allows the top of the liner to expand and contract. It is well known that a flange which is cold on the outside and hot on the inside is liable to crack and, for this reason, it is stated that the plain-top liner is better than refitting a flanged liner. If any objection is offered to the clearance space, then the latter can be filled in with cast-iron cement.

Treatment of Liner Bores after Insertion

Experience shows that the ordinary car-engine liner closes in so as to reduce the liner internal bore when it is an interference fit in the block. The ordinary amount of diameter reduction is about three-quarters of the amount left for interference fit; usually this is about ·003 in. It is necessary, therefore, to hone out the liner to the exact dimension, i.e. the standard cylinder diameter. If connecting-rod slots have been made in the softened end of the liner it is advisable to finish-hone the bottom of the liner first, so that the hone will not pick up when travelling from the hard to the softer material and thus make the softer end a little oversize.

The honing of Brico hardened liners should be done with one of the following grades of honing stones:

For Wet Honing:

Roughing	120 Grit 6 H, or 180 Grit 4 H (Carborundum).
Finishing	2 F.G. 3 H, or 4 F.W. H.

For Dry Honing:

Ammco Impregnated Self-lubricating Stones.
Coarse Stone for roughing cut.
Burnishing Stone for finishing.

Dry honing is very suitable for honing the liner bores with engine in chassis, as it is not necessary to use any paraffin.

Cylinder-liner Equipment

There are three principal methods used for inserting cylinder liners: (1) the " freezing " method; (2) the hydraulic or screw press method; and (3) the screw gear tool.

(1) *The Freezing Method.*—In this the cylinder to be inserted is contracted by lowering its temperature until its external diameter is two or three thousandths of an inch smaller than the cylinder-block bore. The liner is quickly inserted into the block, where it expands as its temperature rises to that of the cylinder block. Liquid oxygen, at a temperature of − 180° F., i.e. 180° + 32° F. = 212° F. below the freezing-point of water,

is used to " shrink " the liners. In the case of a 3-in. diameter liner, the contraction will be from ·006 in. to ·008 in., which is more than the interference fit allowance of ·003–·004 in., so that the liner will readily pass into the cylinder bore. The operator must use well-padded gloves when handling the cold liners. It is necessary to drop the liner centrally and quickly into the cylinder bore, as expansion occurs readily when the liner touches the metal of the block.

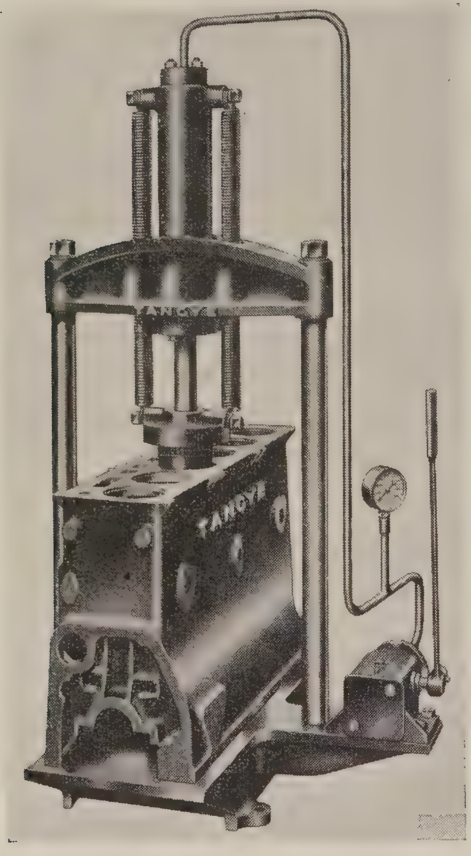


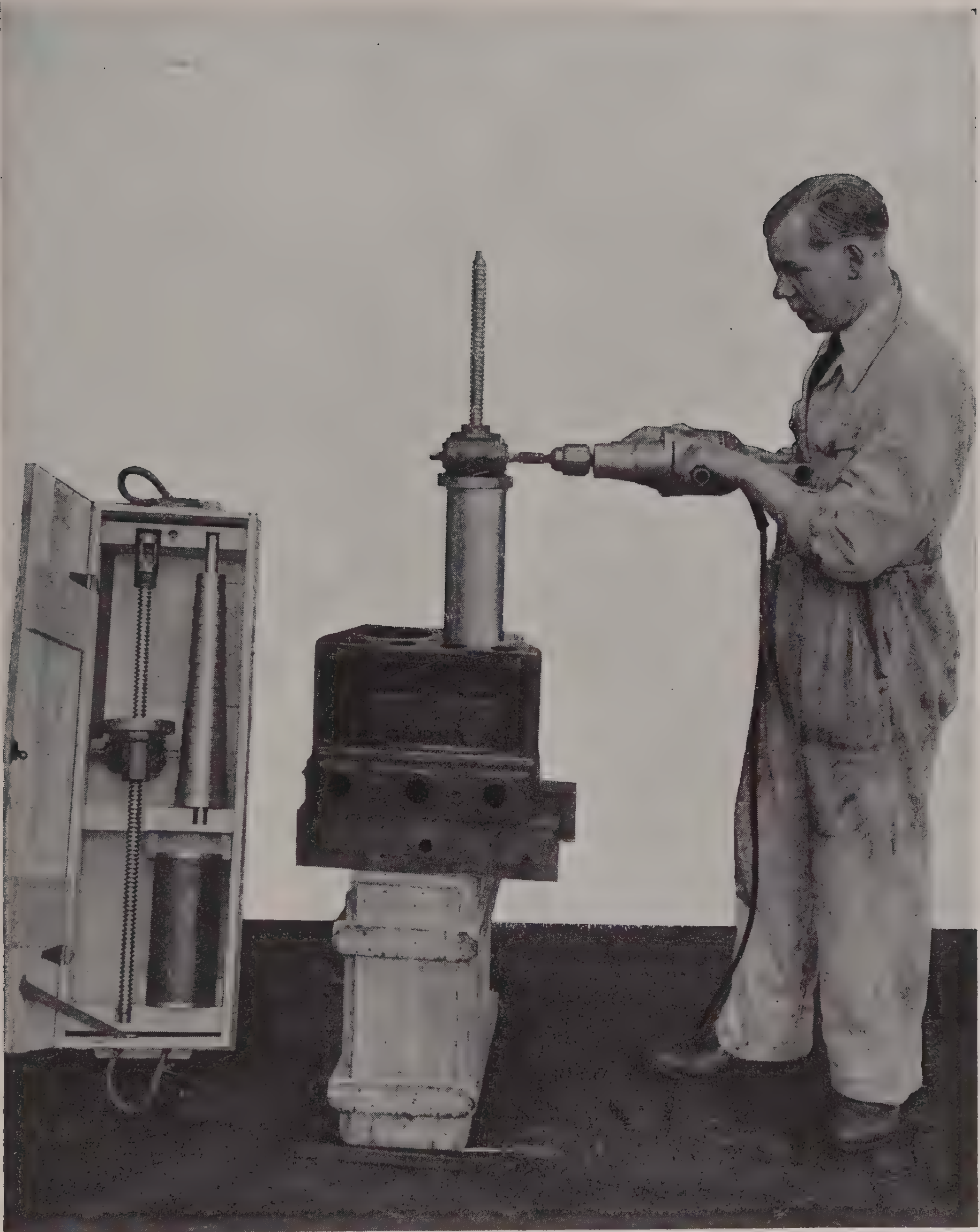
Fig. 477.—The Tangye Hydraulic Press.

(2) *The Hydraulic Press Method.*—Either an hydraulic or a motor garage stand-type screw press can be used on cylinder blocks that have been removed from the chassis. The press should have a capacity of about 10 tons and a longer stroke than the liner length. Usually, a force of about 4–8 tons is required to insert the liner. At first when the liner is inserted the force necessary is much smaller, but as the liner moves farther into the cylinder bore the pressure required increases to the maximum for the last part of the movement. The use of a suitable lubricant on the outside of the liner and inside of the cylinder bore will keep the liner insertion pressure to a minimum value. The axis of the cylinder must be accurately aligned to that of the press ram, and to avoid side force on the liner it is advisable to use a socket type of pressure plate on top of the liner so that the plate can tilt a little should the cylinder axis not be in proper alignment.

Fig. 477 shows the Tangye cylinder-liner press,[1] consisting of a stand for the cylinder block having two strong steel pillars and a rigid cross-beam unit containing the hydraulic cylinder. The ram has an enlarged head connected on either side to projections on the top of the cylinder by long helical springs. When the pressure on the ram is released these springs return the ram to its highest position. Pressure is applied to the ram cylinder by means of a hand-operated pump mounted on the lower part of the stand. A pressure gauge is fitted on the delivery side, and its readings afford a useful guide as to the force that is applied to the liner at any moment.

The screw press employed in motor-garage workshops for extracting or

[1] Brown Bros., Ltd., London, E.C.2.



(*Courtesy Brown Bros., Ltd.*)

THE UNIQUE CYLINDER SLEEVE INSERTION TOOL, SHOWN OPERATED BY PORTABLE ELECTRIC DRILL.

inserting bushes, riveting crown wheels, and straightening bent components can usually be adapted to liner-fitting purposes.

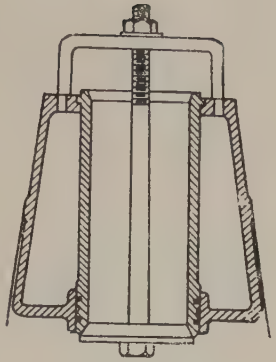


Fig. 478.—Withdrawing Cylinder Liner.

A simple home-made device used for withdrawing the wet-type cylinder liners of high-speed oil engines is shown in Fig. 478. In this example, a long bolt, with a conical-faced washer to engage with the lower end of the liner, is used in conjunction with a yoke piece and nut above. The outer diameter of the liner washer must be slightly less than that of the outer diameter of the liner itself in order to clear the cylinder block as the liner is pulled upwards. A similar tool, used in the reverse sense, can be employed for inserting the liner.

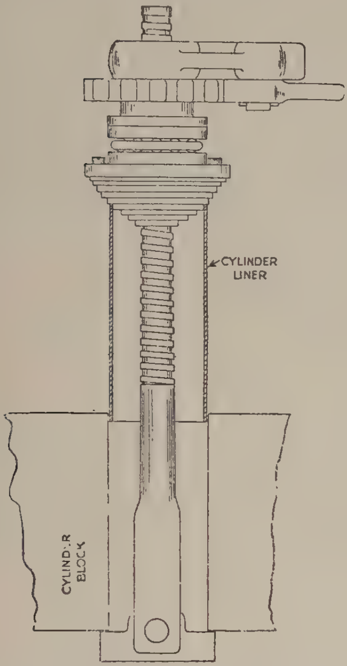


Fig. 479.—The Buma Tool inserting Cylinder Liner.

(3) *Screw Gear Tools.*—There are several makes of cylinder-liner removal and insertion tools available that are based upon the screw and nut principle. Typical examples are the Unique, Buma, and Ohio liner tools.

The Unique liner tool, which can be used for cylinder blocks on the bench or in the chassis, consists of a long shaft screwed with a square thread along which a nut member is rotated against the pressure plate that engages the cylinder liner. Special bars and plates of various sizes enable a wide range of liner dimensions to be covered by this tool. Instead of operating the nut unit by hand it is provided with a pair of gears, so that a right-angle shaft member can be attached to and driven by an electric drill of $\frac{5}{8}$–$\frac{3}{4}$ in. capacity. The insertion or extraction of a liner, for diameters up to $4\frac{1}{2}$ in., is usually a matter of several minutes only.

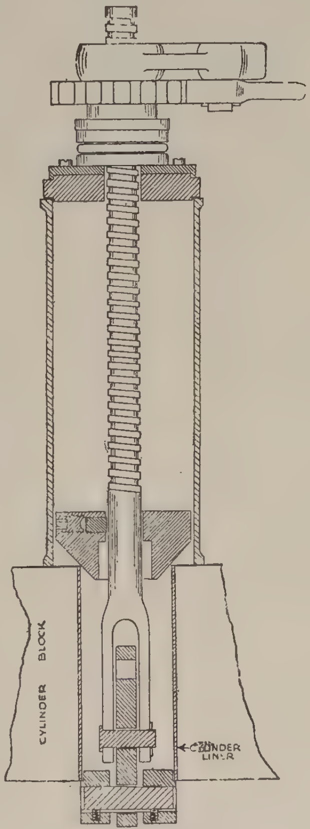


Fig. 480.—Removing Cylinder Liner with Buma Tool.

The Buma tools for inserting and withdrawing cylinder liners are shown in Figs. 479 and 480. The former illustration depicts the tool as adapted for inserting the liner. It has a stepped cone which quickly centralises the liner, a square-thread screw with T-yoke below and a ratchet-head nut for forcing the liner downwards. The thrust is taken on a heavy ball-thrust bearing, so that no friction is set up on the liner. This device can be used for fitting liners with the engine in or out of the chassis. For removing the liners, the attachments shown in Fig. 480 are employed. These consist of a fork-ended square-thread screw and slotted cylindrical blocks made with recesses or shoulders outside to engage with the edge of the cylinder liner. The drawheads are adjustable and the conical member shown centralises the bar and holds it in position while the other attachments are being fitted.

The Wet Type of Liner

This design of liner is made of greater thickness than the dry type, since it has no external support, except at the two ends, and thus has to withstand most of the cylinder-pressure loads. Whereas dry liners can be made from $\frac{1}{8}$- to $\frac{3}{16}$-in. thickness, wet liners are usually of $\frac{1}{4}$- to $\frac{3}{8}$-in. thickness for commercial engines and $\frac{3}{16}$- to $\frac{1}{4}$-in. for car engines.

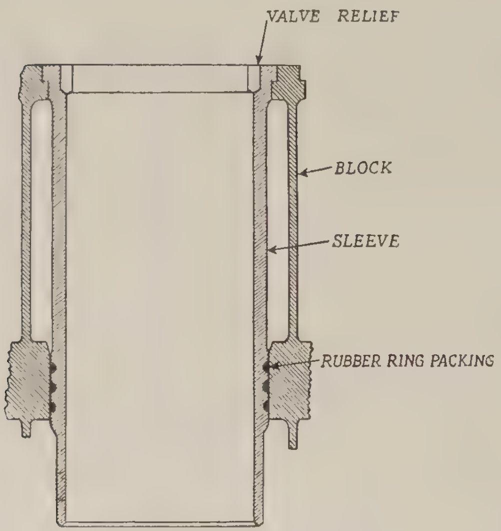


Fig. 481.—Typical Wet Liner for High-speed Oil Engines.

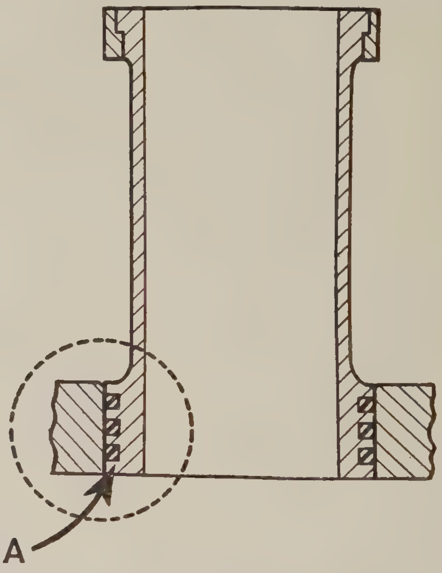


Fig. 482.—Wet Type of Liner, showing Square-section Rubber Rings at A.

It is the common practice to provide a flange at the top end, to fit into a corresponding recess in the cylinder block; the cylinder head is sometimes arranged to come into contact with this flange; the flange and upper part of the liner are made a press-fit in the cylinder block.

The lower end of the liner is often provided with two or three rubber rings, which not only afford a satisfactory water seal but also permit the necessary expansion to occur. Fig. 481 shows a typical wet-type liner with a flanged upper end and a three-rubber-ring water-tight joint at the lower one. The rings are now made of a special grade of artificial rubber that will withstand the effects of heat, oil, and water indefinitely, so that the material does not perish in the manner of natural rubber.

Sometimes the liner is made an interference fit in the upper part of the cylinder block, the outside diameter being from $\frac{2}{1000}$ to $\frac{4}{1000}$ in. greater than the diameter of the cylinder-block hole into which it is fitted.

When inserting wet liners it is important to lubricate the outer surfaces. The usual practice is to *smear the outside of the liner with soft soap*, as this material acts as a lubricant as well as affording a good seal after insertion.

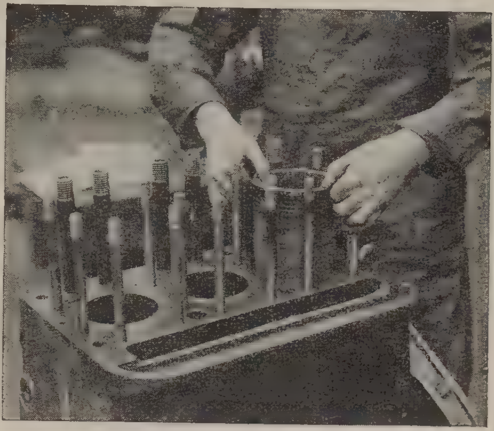


Fig. 483.—Inserting Wet Type of Liner in Oil-engine Cylinder Block.

Cleaning the Reconditioned Cylinder

After a cylinder has been reconditioned by boring, honing, or grinding, every trace of abrasive, turnings, dust, etc., must be removed from the whole of the inside of the casting. This can be done by means of a paraffin spray or bath, followed by immersion in hot caustic soda solution, for iron cylinders; the latter solution should not, however, be used for aluminium cylinders.

A useful device for removing grit is the Buma "Storm GR" one illustrated in Fig. 484. This can be readily fitted into position below the engine by inserting it through from the top; it prevents any abrasive or other solid matter from getting into the bearings.

A special pair of hand-operated tongs is furnished to clamp on the special connection in the inside of the rubber funnel, and the operator then pushes the complete unit down through the cylinder.

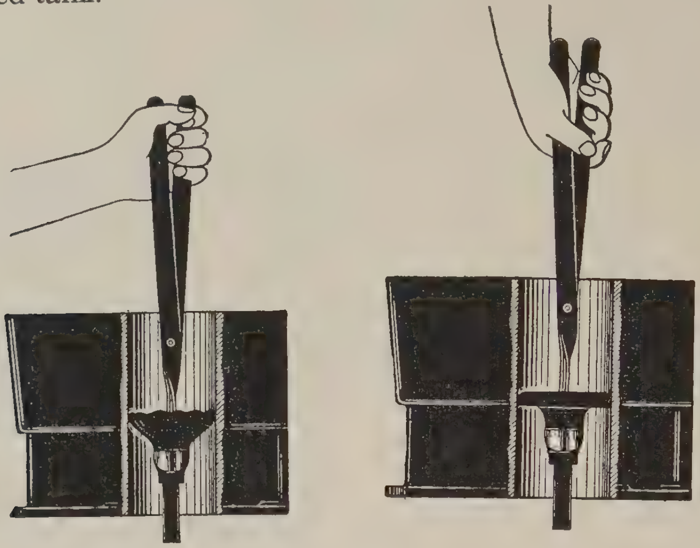
The rubber cup collapses when inserted through the cylinder, but expands out to its normal size upon reaching the bottom.

A flexible tubing is then hooked on to the lower end of the rectangular-shaped flue; the weight of the tubing holds this connection in place, so there is no leak at this point.

At the lower end of unit, a pointed shaft contacts the floor, compressing a spring which holds the rubber cup against the bottom of the cylinder.

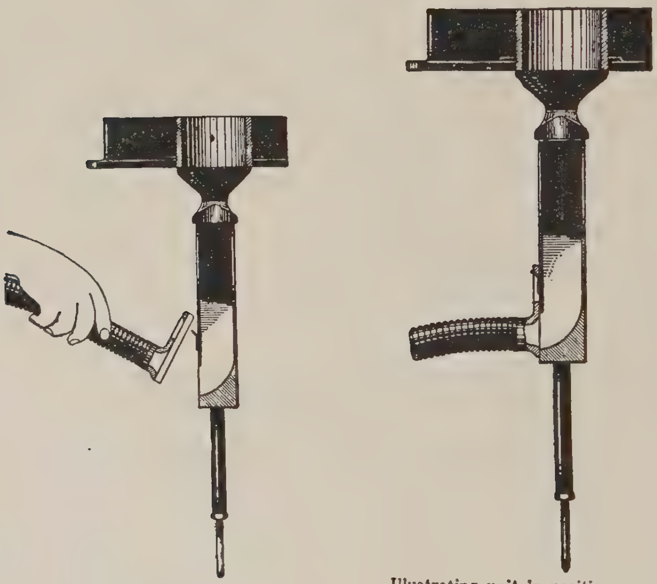
A guard made in halves is now slipped around the boring bar at the top of the cylinder to increase air speed at this point.

The unit is now ready for operation. By turning the switch on the motor operating the fan located at the top of the vacuum tank, the vacuum created in the tank pulls all grit and dust down through the cylinder into the funnel through the rectangular-shaped flue out through the flexible tubing into the sealed tank.



When inserting unit through cylinder, rubber funnel collapses.

Removing unit through cylinder, rubber funnel turns inside out.



Hooking tubing on flue.

Illustrating unit in position.

Fig. 484.—The Buma Method for removing Grit from Reconditioned Cylinders.

To remove the Storm Grit Remover from the cylinder it is only necessary to unhook the flexible tubing, insert the special tongs down through the cylinder, and attach them to the special connection provided in the unit, pulling the whole unit up through the cylinder. The rubber funnel turns inside-out while coming up through the cylinder.

Replacing the Cylinder Head

In concluding this chapter it may not be out of place to mention the methods usually adopted in connection with the replacing of the cylinder head.

Fig. 485 shows a typical engine cylinder and its cylinder head, the copper and asbestos gasket being shown on the top of the studs. The machined surfaces of the cylinder and its detachable head having been cleaned thoroughly of all dirt particles and burnt oil, the gasket, if undamaged, may be used again, and should be smeared with linseed oil, shellac, or one of the special compounds, such as "Osotite."

In some cases engine manufacturers recommend that the copper-asbestos gaskets should be inserted with the smooth side on top; in others, underneath. Since, however, it is equally important to have a gastight joint on both faces of the gasket, the way up of the latter does not appear to be of great importance.

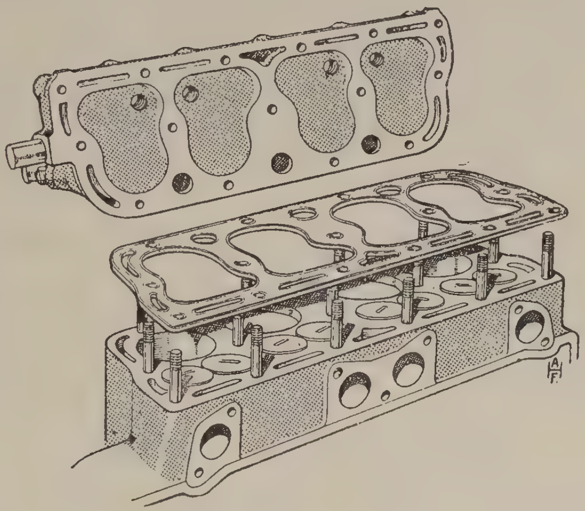


Fig. 485.—The Cylinder-head Joint.

In the Vanguard engine, where flanged cylinder liners are used, since it is necessary, when breaking the cylinder-head joint, not to disturb the sleeves, the manufacturers recommend that the underside of the gasket should be coated with jointing compound and the upper side with grease. The cylinder-sleeve " figure of eight " packings should be similarly treated for the same reason.

Some American engines are fitted with single metal gaskets, as distinct from the copper-asbestos ones, which yield a little on tightening up the cylinder-head nuts. These gaskets should be examined for defects, after cleaning. If found to be satisfactory, jointing compound should be smeared lightly on both faces. Before replacing the cylinder head see that all stud threads are free, and that there is no dirt around the feet of the studs.

It is important to tighten down the nuts on the cylinder-head studs in the correct order. The instruction book of the manufacturers usually shows the order recommended for this procedure.

After tightening down the cylinder-head nuts, the radiator and water jackets should be filled with hot water and the engine run for a time, until it is quite hot. The nuts should then be given another check, with the spanners, for tightness; it will usually be found that they can be given half a turn.

It is a good plan to check over the nuts again after the vehicle has run about 500 miles or so.

Grinding Detachable Heads

In the case of many motor-cycle cylinders having detachable heads with circular register lips, it is possible to true up the joint faces by grinding them together with valve-grinding compound until both the cylinder head and the cylinder faces are free from scratches.

The joint is then made with gold size or boiled linseed oil, no washer or liner being necessary.

Surface-grinding Machine for Cylinder Heads, etc.

It will often be found, on removing cylinder heads of four- and six-cylinder engines that the machined faces are warped, owing to heat and screwing-down distortion effects; sometimes as much as ·010 to ·020 in. distortion can be measured (Fig. 486). This is more particularly marked in the case of aluminium heads.

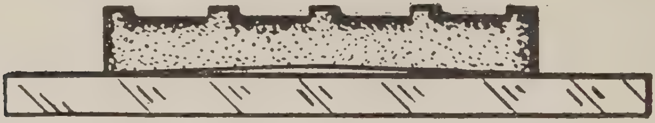


Fig. 486.—Illustrating Distortion of Cylinder Head.

Special surface-grinding machines are now available for truing up cylinder heads, inlet and exhaust manifolds.

The Van Norman machine (Fig. 487) uses an annular grinding wheel which cuts on its upper end face. It is provided with an accurately machined flat table fitted with an adjustable fence or guard against which the head is moved or guided whilst it is being reground. The operation of truing the machined face of a cylinder head takes only a few minutes and an accurately flat and smooth surface results.

The grinding wheel of the No. 555 machine shown is 11-in. diameter and it is tilted, slightly, so that only one part of the flat grinding surface is presented to the head or manifold flange. A diamond dressing device is provided for the grinding wheel. Vertical feed movement is regulated by means of a micrometer dial-operated feed unit.

It may be added that when *cracked cylinder heads* or blocks have been repaired by welding, their flat machined faces can be trued up on this type of machine.

Exhaust manifolds, due to their high working temperature and nut-tightening stresses, frequently become distorted and on dismantling engines they should be checked on a surface table or with a straight-edge for flatness or alignment. Both inlet and exhaust manifold faces can be trued on the machine shown in Fig. 487.

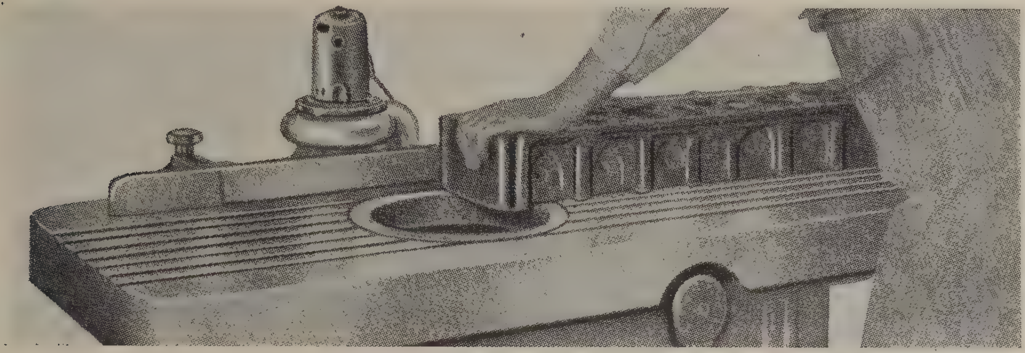


Fig. 487.—The Van Norman Cylinder-head Grinder.

CHAPTER 13

THE ENGINE-LUBRICATION SYSTEM

In view of the importance of the lubricating system in maintaining the working surfaces of the engine in proper condition over the range of engine speeds and for long periods of service, it is essential that the motor mechanic and engineer should be conversant, not only with the working principles, but also the maintenance, repair, and adjustment of the various systems in use. Although the modern engine seldom gives trouble with its oiling arrangements, when such trouble does occur it is often unnoticed until its effects upon the engine's performance are more or less suddenly apparent. Thus a failure of the oil delivery to the main and big-end bearings, if not soon detected, will usually result in seized or " run " bearings and, in some cases, of scored cylinder walls due to piston seizure.

Whilst space limitations prevent any detailed descriptions of the various lubricating systems in use, a general account will be given of typical modern systems, with notes on the troubles likely to be experienced, adjustments, and maintenance instructions.

Modern Oil Systems

There are two principal engine lubrication systems in general use, namely, the *pressure* and the *dry-sump* ones; the former is the more widely used on account of its cheaper cost of installation.

The *pressure system* employs an oil pump of the plunger, gear, or sliding-vane rotary pattern—driven from the camshaft, or crankshaft, which draws oil from the sump in the base of the crank-chamber and forces it under pressure to the crankshaft main bearings and big-end bearings (Fig. 488). In some instances oil is fed under pressure to the gudgeon-pin and camshaft bearings. Where overhead valve rockers or camshafts are employed to operate the valves, their bearings are lubricated under pressure also.

The cylinder walls, in the majority of cases, depend for their lubrication upon oil thrown about by the crankshaft and big-end, but in some instances a positive supply of oil is fed to each cylinder wall near its lower end. Sometimes an oil trough is kept supplied by the pump, and the piston's lower edge is arranged just to dip into this oil, at the bottom of each downward stroke; this method is seldom used in English practice today.

In some cases a hole is drilled through the top half of the connecting-rod bearing, to correspond with a hole through the crank-pin,[1] so that at each revolution, when these holes correspond, oil is forced out in a slanting direction, upwards, on to the cylinder walls. This oil jet affords a positive method of ensuring that each cylinder barrel receives an adequate supply of oil.

The timing gears are usually lubricated by a small oil jet or by leakage from the main crankcase; sometimes, however, the oil-pressure release discharges its surplus oil into the timing case, whence the unused oil drains back through suitable holes or passages into the main crankcase.

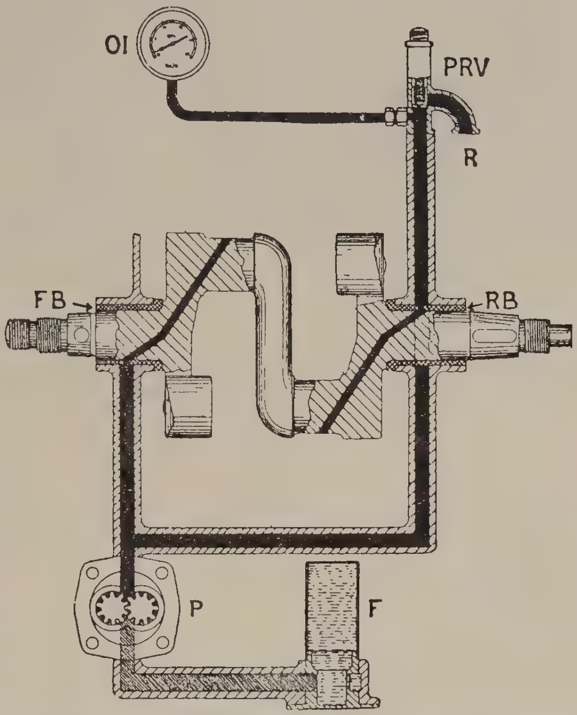


Fig. 488.—The Jowett Two-cylinder Engine Pressure Lubrication System. P—Pump. F—Filter. FB—Front Bearing. RB—Rear Bearing. OI—Oil-pressure Gauge. PRV—Pressure-release Valve. R—Overflow, or Return Pipe.

Components of Lubrication System

Commencing with the engine sump, this detachable unit is at the bottom of the crank-chamber, and is held by a large number of studs and nuts; a drain plug is provided for emptying the sump. The top of the sump is provided with a metal-gauze filter to trap any deposits in the oil before they can drain back into the sump. This gauze filter should be cleaned in paraffin or petrol bath each time the engine is decarbonised.

The *oil sump* is provided with a large-size oil filler (having a gauze filter as a rule) and an oil-level dip-stick or float gauge.

The *oil pump* may be situated above or below the level of the oil in the sump; in the latter case it is self-priming. Of the three types of oil pump that have been used, the sliding-vane pattern has definitely dropped out of use, the gear-wheel form of pump (Fig. 489) being the most widely employed. The plunger-pattern pump (Fig. 490) is the other type still in active use.

The plunger-type oil pump is provided with two valves, usually of the

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[1] *See* Fig. 393, p. 316.

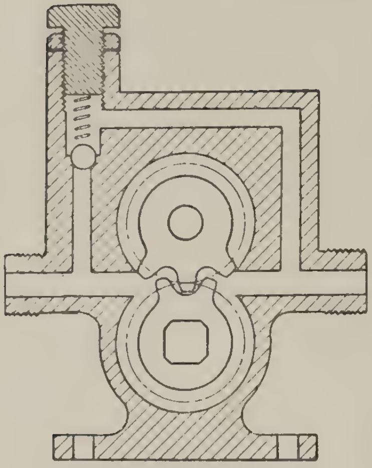

Fig. 489.—Typical Gear-wheel Pump. The upper wheel rotates clockwise.

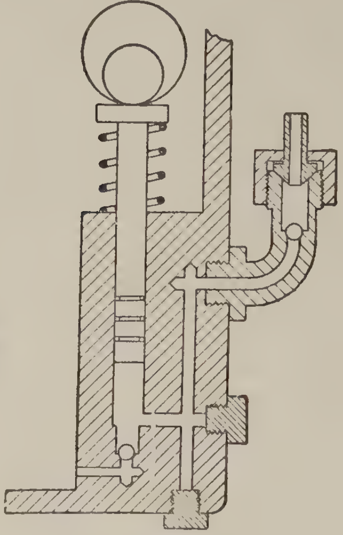

Fig. 490.—The Plunger-type Oil Pump.

spring-loaded ball or plain ball type. One of these is a non-return valve on the suction side; it allows free passage of the oil sucked up by the pump but prevents return of any of this oil to the sump. The other non-return valve is placed on the delivery side and allows oil to flow from the pump to the pipes feeding the bearings, etc., but prevents flow back in the reverse direction. The submerged gear-wheel pump has no valves, whilst the high-level gear-wheel pump usually has a foot valve.

The Austin A40 Oil-pump Assembly

Fig. 491 illustrates the oil-pump assembly of the Austin A40 engine, the various components of the pump, filter, and oil-pressure relief valve being indicated by the numbers and described in the caption below.

The spiral-gear meshing type of oil pump shown at (3) and (4) in Fig. 491 is employed, and it is driven from a spiral gear on the rear part of the camshaft through a vertical shaft. The pump can be removed by disconnecting the oil-supply pipe from the pump body to the crankcase (see also Fig. 495). The two

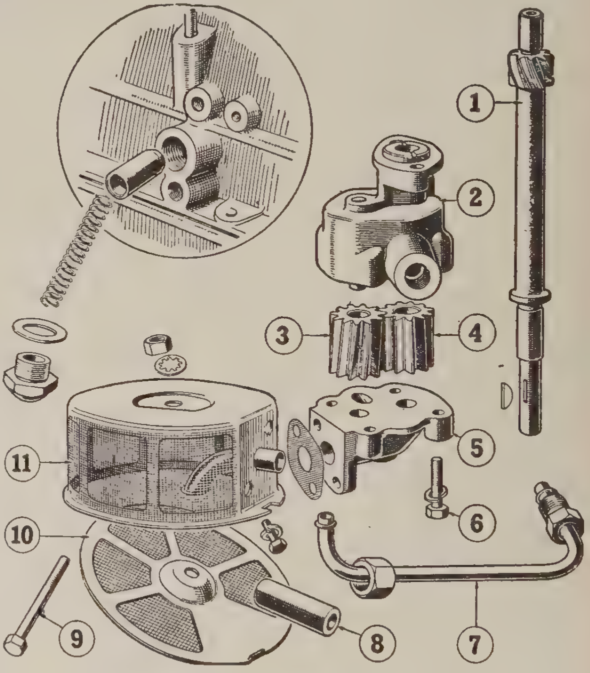

Fig. 491.—The Austin A40 Oil-pump Assembly.

1, Driving Spindle. 2, Oil-pump Body. 3, Driven Gear. 4, Driving Gear. 5, Bottom Cover. 6, Set-screws and Washer. 7, Oil-delivery Pipe. 8, Distance Piece. 9, Set-screw. 10, Bottom Cover. 11, Oil-strainer Body.

Note.—The inset drawing, above, shows the oil-pressure relief-valve assembly.

nuts and washers are then removed from the upper flange of the pump, when the complete unit can be drawn out of the crankcase.

The pump is dismantled (after first marking the two flanges to assist reassembly) by removing the four long set-screws from the body and separating the bottom cover. The driven gear is then lifted out. The driving gear is keyed to the spindle and must be tapped off, upon removing the key from the spindle, to allow the latter to be withdrawn from the body. When the parts are reassembled and the screws tightened up, the pump should be rotated by hand to ascertain that it works quite freely.

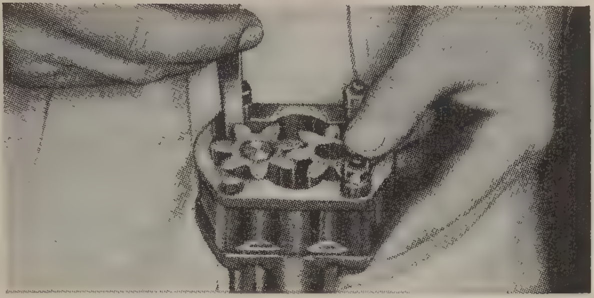

Fig. 492.—Checking the Clearance between Impeller Gears and Pump Body.

Servicing Gear-type Pumps

After dismantling and cleaning the components of this type of oil pump the gears should be placed back in the pump casing, but without replacing the cover. The gear teeth should be examined for signs of burrs, and if any are found these should be removed with a smooth file.

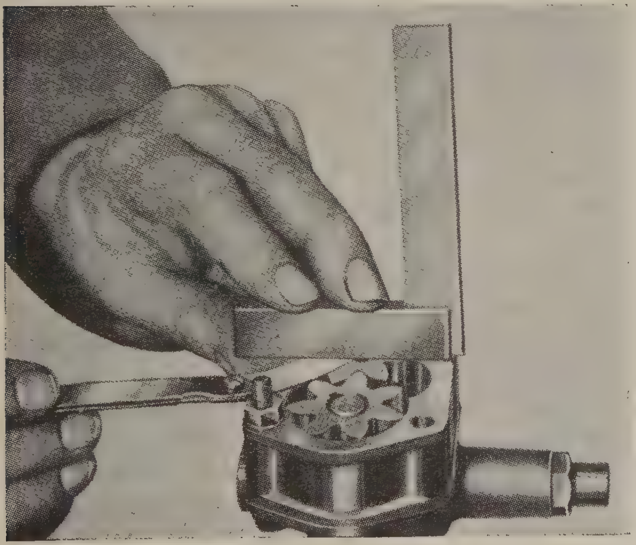

Fig. 493.—Checking the End Float on the Oil-pump Gears.

The clearance between the gears and the pump body should be checked and compared with the manufacturers' new values. Fig. 492 illustrates the method of checking this clearance in the case of the Bedford and Vauxhall Velox and Wyvern oil pumps. The narrow feeler gauge is inserted, as shown, between the crests of the gear-wheel teeth and the inside of pump body.

In the case of the Vauxhall engines mentioned this clearance, when new, lies between ·006 in. and ·0085 in. (radial value). For the Bedford (Models K, M and O) the radial clearance is ·0025–·0055 in. If, on checking these clearances, the values are found to be excessive, new gears should be fitted, provided the body portion does not reveal signs of wear; otherwise it may be necessary to fit a new pump unit.

The end clearance, or float, of the gears should also be checked in the manner illustrated for the Bedford and Vauxhall engines in Fig. 493, using a feeler gauge and the base of a set-square—to take the place of the cover—to measure this clearance.

The end float of the Vauxhall and Bedford oil-pump gears should be ·0035–·006 in. This should not be confused with the end clearance of the pump spindle, which should be ·0015–·003 in., and is governed by the position of the driving collar on the spindle.

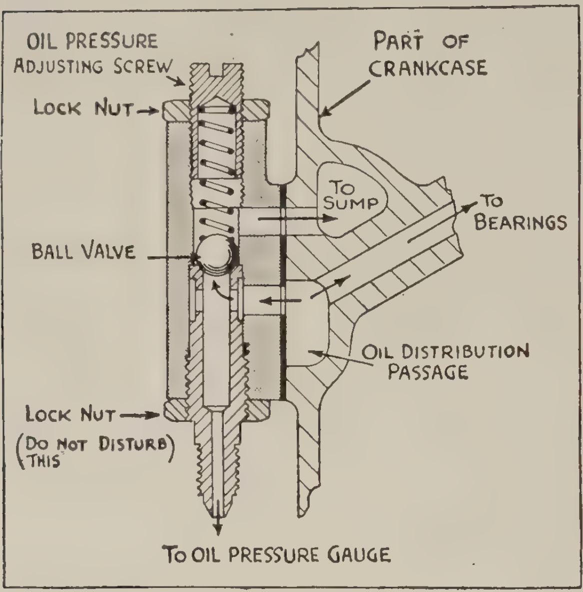

Fig. 494.—Typical Oil-pressure Release Valve.

The Oil-pressure Relief Valve

The oil-pressure relief valve is provided for the purpose of regulating the pressure of the oil delivered by the pump to the value that has been found to be the most satisfactory for the engine by the manufacturers. In most cases this valve should not be tampered with during the normal operating life of the engine, but when the engine is completely overhauled this valve assembly should be dismantled, cleaned, and examined for signs of wear. The principle upon which the pressure relief valve operates is illustrated in Fig. 494, which is a diagrammatic sectional view of a typical layout. Oil, delivered under pressure from the pump, first passes to the relief valve, which consists of a helical spring-loaded ball valve in this case. In some engines a conically seated valve is used. The tension of the spring on the valve is adjusted, by means of the screw above—after releasing the locknut shown—until the oil pressure necessary to lift the valve is the correct value for the oil supply to the main and big-end bearings. Therefore the oil can flow to these bearings only when the pressure is high enough to lift the non-return valve. The actual value of this pressure is shown on an oil gauge mounted on the instrument board of the vehicle, and the reading of the gauge indicates whether the lubrication system is operating satisfactorily; this subject is dealt with more fully later in the present chapter. It will be evident that, by increasing the pressure of the spring on the ball valve, shown in Fig. 494, *the oil pressure in the system will be increased*; conversely, by reducing the pressure, by unscrewing the adjusting screw, *the pressure will be lowered.*

Referring to Fig. 491 again, the components of the oil-relief or release-valve unit are shown in the upper left-hand inset circle. The valve in this instance is a conical-faced hollow plunger which is held on its seating by the spiral compression spring and the hexagonal-headed plug that screws into the crank chamber. No adjustment of the spring tension is provided, so that it is not possible to alter the pressure arranged for by the engine designer. When the relief valve is dismantled for cleaning and examination, the seating and plunger end should be checked for signs of wear or damage and that the passages in the crankcase are clear of foreign matter. When reassembling, the fibre washer fitted under the head of the valve plug (see Fig. 491) must be cleaned and replaced to ensure an oil-tight joint.

In the case where an *oil cooler* is fitted, this is usually arranged on the delivery side of the oil pump. The oil passes through the pump and thence through the oil cooler to the pressure release, pressure gauge, and main bearings.

The lubricating oil, in the course of its circulation around the engine, has to pass through an oil cleaner to get rid of any solid particles which would otherwise tend to cause increased bearing and cylinder wear. The *oil cleaner* (to which fuller reference will be made later) is usually placed on the delivery side of the pump, so that all of the hot (thinner) oil is forced through the filter before it reaches the bearings.

Typical Lubrication Systems

If the lubrication systems of various modern engines be examined in detail, it will generally be found that these follow the same principles and have similar components, although there are certain minor design differences. It is therefore necessary to describe only two or three typical and representative engine lubrication systems in order that the reader may understand most other ones.

Taking as the first example the *lubrication system of the Austin A40* engine, the oil-circulation system is shown clearly by the arrows in the front and side sectional views given in Fig. 495.

Commencing at the stage where the hot used oil from the bearings, etc., drains back into the sump at the bottom of the crankcase, this oil is drawn through the large gauze filter shown at the base by the suction of the oil pump, and is forced under pressure to the main oil gallery. This runs the length of the engine on the right-hand side; the main oil delivery to the bearings is made from this gallery. A proportion of the oil passing to the main gallery is circulated through an externally fitted oil filter[1] and is

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[1] *Vide* page 422.

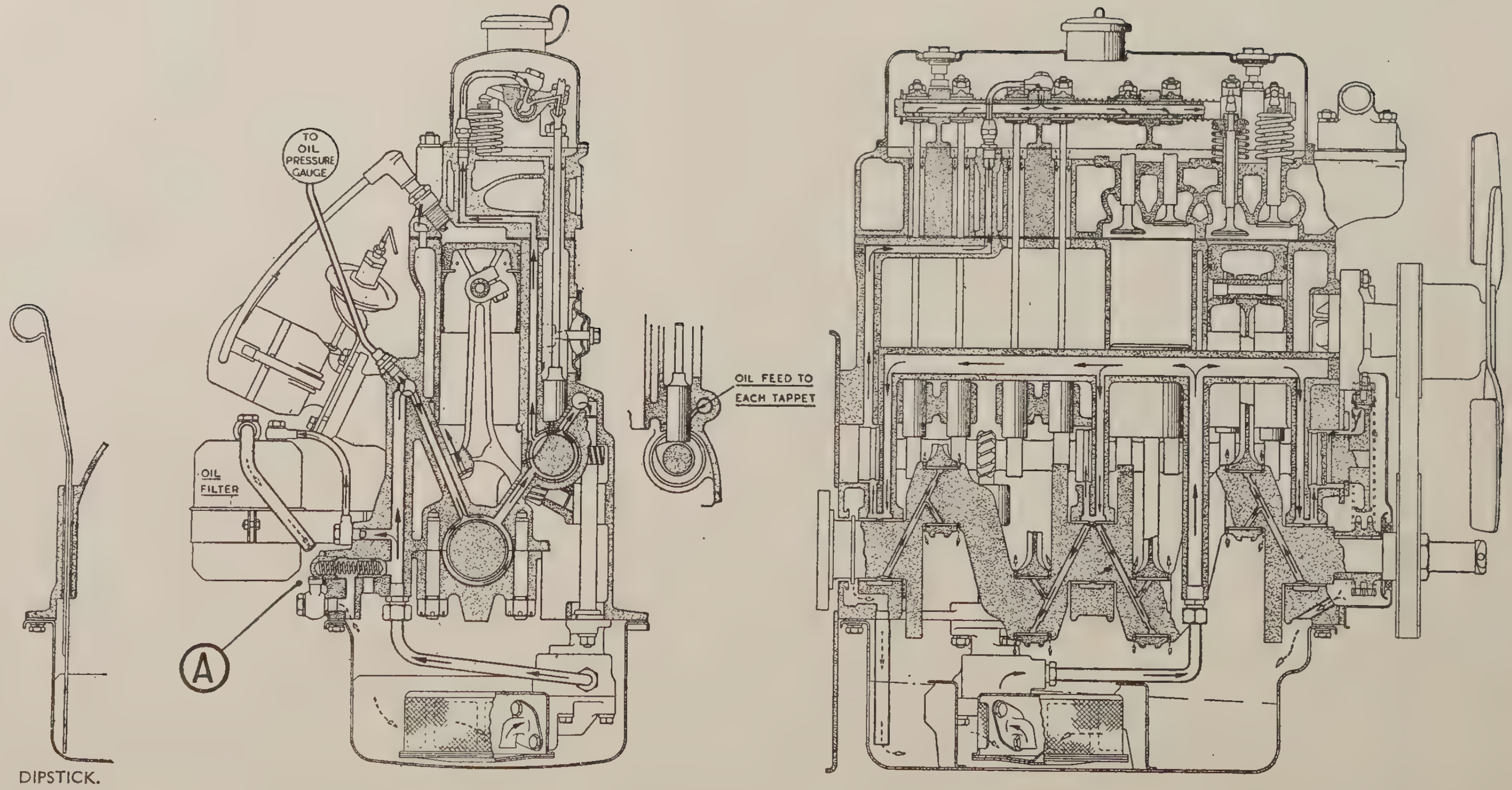


Fig. 495.—The Austin A40 Lubrication System

returned direct to the sump. The spring-loaded oil relief valve, described earlier, is located between the pump and main gallery, as shown at A in Fig. 495; the overflow from this valve is returned to the sump. From the main gallery oil under pressure is fed to the main bearings and big-end bearings through the drilled crankshaft, as shown in the right-hand diagram in Fig. 495; also to the three camshaft bearings. Each tappet is lubricated from a small oil gallery running the length of the engine on the left-hand side.

From one camshaft bearing, oil at reduced pressure is taken through drilled passages in the cylinder block and head to an oil-feed collar on the valve rocker shaft and thence to the hollow shaft itself. The surplus oil, after circulation, returns from the rocker gear *via* the push-rod holes back to the sump. The oil circulation from the camshaft bearing to the rocker shaft is shown in the left-hand diagram of Fig. 495. The camshaft on its front bearing is drilled right through, and grooves are cut on either side which lead from this drilling to the front face. The camshaft thrust plate has one hole drilled to match up with these grooves, so that each time one of these grooves comes opposite this hole a jet of oil will pass through the thrust plate under pressure. This oil is picked up by the specially designed camshaft timing wheel, and by centrifugal action is passed to the timing chain.

Referring to the left-hand diagram of Fig. 495, it will be observed that the oil-pressure gauge is connected to the main gallery, and thus indicates the delivery pressure of the pump and also whether the oil system is working correctly. The normal pressure during ordinary running of the A40 engine should be between 25 and 30 lb. per sq. in.

The Morris Six engine is of the overhead camshaft pattern, the camshaft being driven by means of a vertical shaft from the engine, *via* skew or helical gears at the engine and camshaft ends. An extension of this shaft drives the gear-type oil pump near the bottom of the sump. Fig. 496 illustrates the lubrication system in perspective view, the course of the pressure oil flow being denoted by the white arrows.

The oil to the pump is drawn through a floating-type oil filter, and from the pump it is delivered to a Tecalemit filter built into the sump. A relief valve is provided in the delivery passage between the pump and the filter to deal with any high pressure developed whilst the oil is cold; the surplus oil is returned to the sump.

From the centre of the filter the cleaned oil passes through the filter end cover housing the balance valve and through a drilled passage to the main oil gallery which runs from front to rear of the engine. The balance valve in the filter element cover is provided to ensure, in the event of excess pressure or a blocked filter, that the oil is fed to the main gallery. From the latter the oil is fed to each crankshaft main bearing and from the rear end bearing a vertical passage delivers the oil to the rear-camshaft bearing housing. The remaining camshaft bearings are lubricated by oil delivered to them from the rear bearing through the centre of the hollow camshaft.

The oil escaping from the ducts in the camshaft bearings lubricates the cams and tappets, and then drains back to the sump through passages provided in the cylinder head and block. Surplus oil from the big-end bearings splashes on to the cylinder walls and lubricates the pistons and small-end connecting-rod bearings. An oil pipe at the rear of the main oil gallery is connected to the oil gauge on the instrument panel.

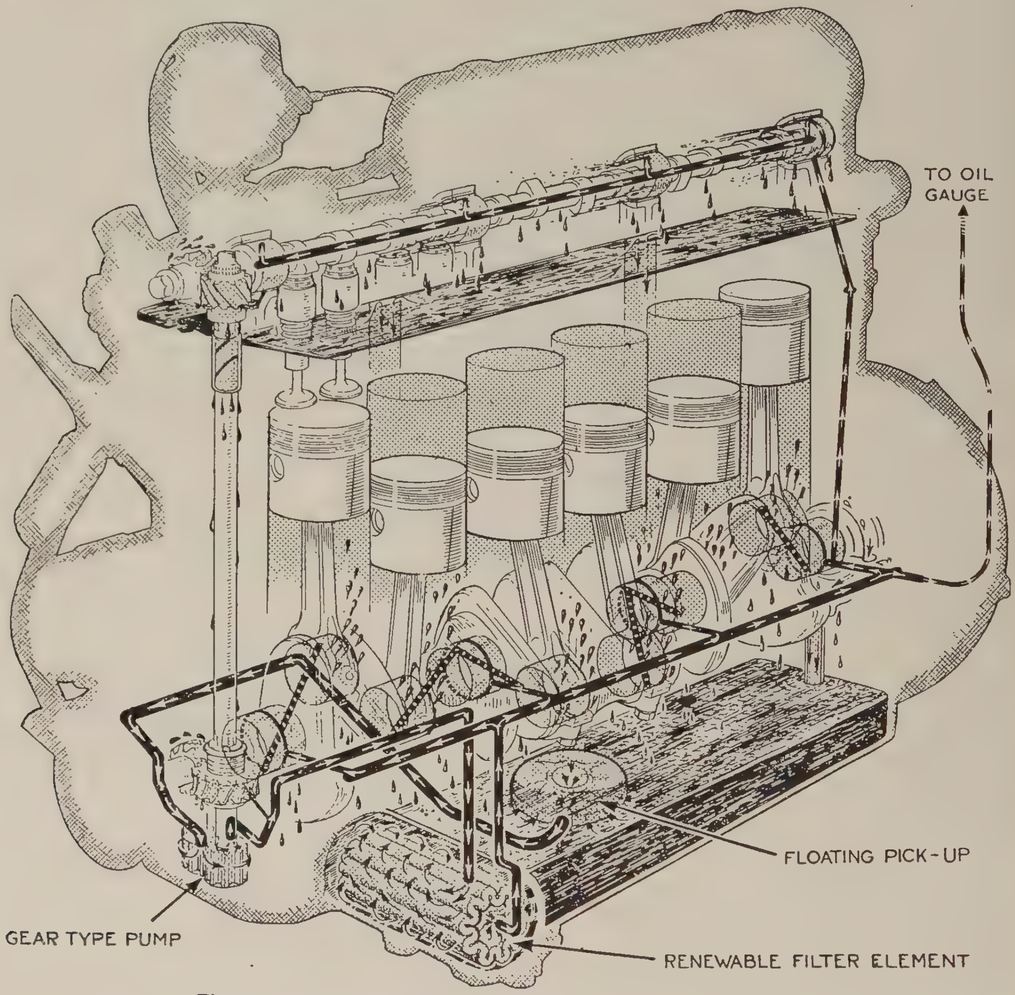
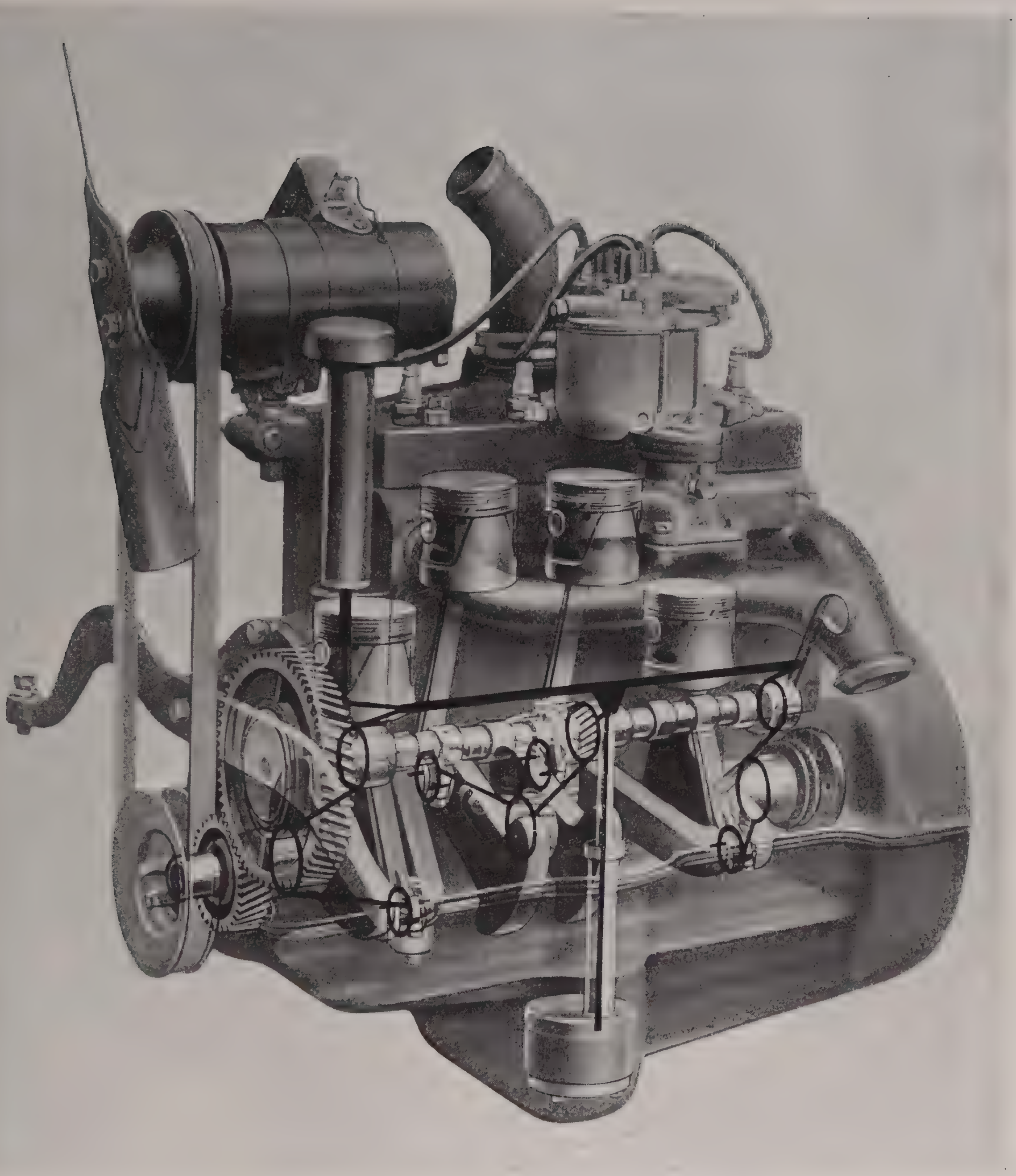


Fig. 496.—Lubrication System of Morris Six Overhead Camshaft Engine.

The oil-pressure relief valve is of the non-adjustable ball type, and is mounted in the front housing assembly to the left of the crankshaft pulley. The valve operates when the pressure exceeds 80 lb. per sq. in.

The Ford 8-h.p. and 10-h.p. lubrication system, illustrated in the plate facing this page, is a relatively simple but thoroughly sound one. The course of the oil is shown by the black lines. The vertical shaft-driven pump in the oil sump delivers oil to the main oil gallery above the cam-



THE FORD EIGHT LUBRICATION DIAGRAM.

The black lines indicate the oil paths.

shaft, from which the oil goes to the three camshaft and three main crankshaft bearings and through drillings in the crankshaft to the crankpin or

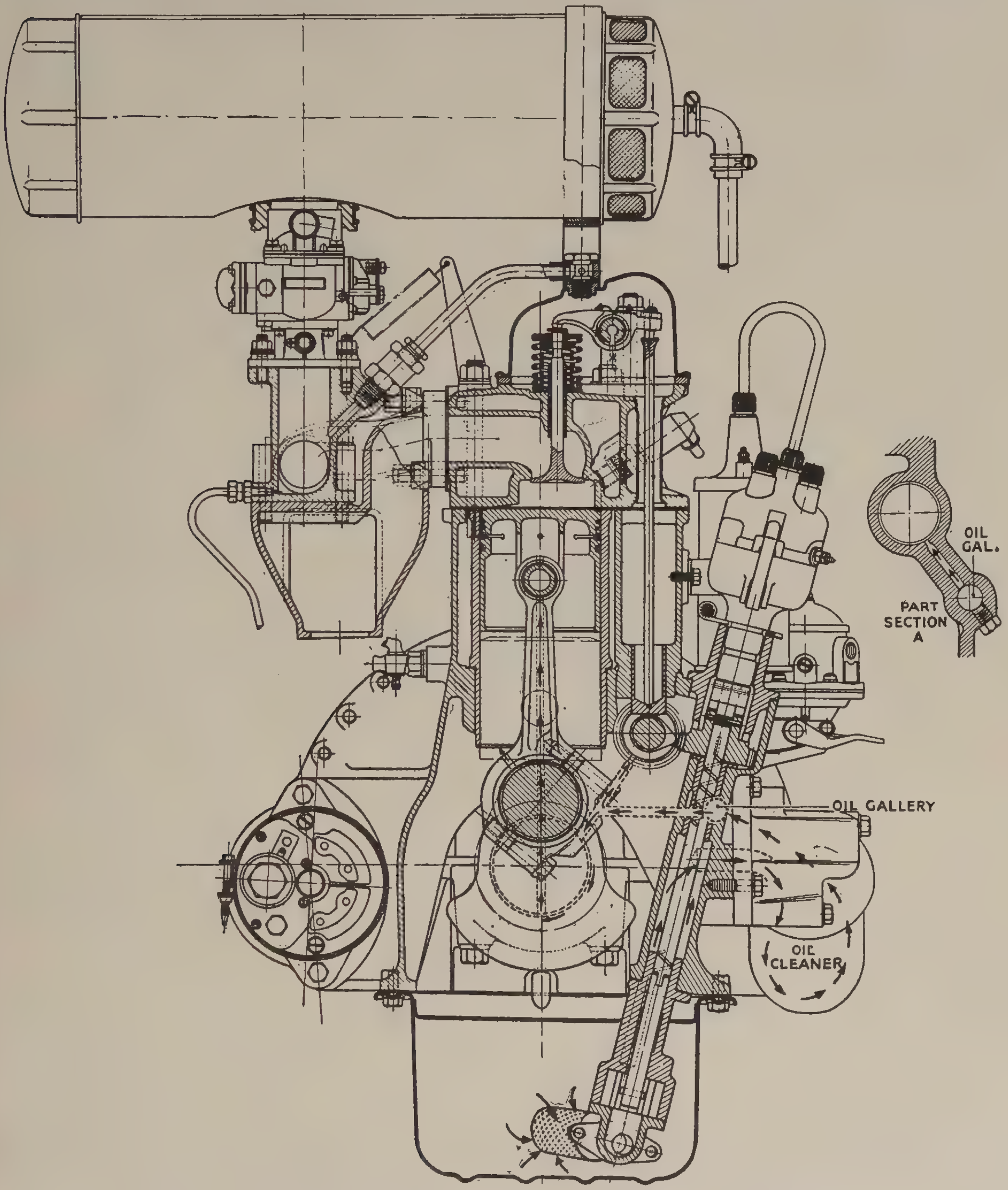


Fig. 497.—Lubrication System of Standard Vanguard Engine (Front Elevation).

big-end bearings. The later model Ford Anglia and Prefect engines employ roller-chain drives to the camshaft instead of the gear drive shown in the plate; otherwise the lubrication system is identical. The chain sprockets, chain tappets, and cylinder barrels are all splash-lubricated. There is an external oil filter which has a replaceable filter element that should be changed every 7,000 miles. No oil-pressure gauge is fitted to these engines, but a gauge is available that can be fitted, if required.

The Standard Vanguard engine lubrication system is shown in Figs. 497 and 498, and as this system has certain novel features it will be briefly outlined. The oil pump is of the *double rotor type*, having a centre smaller rotor driven by a short shaft. The two rotors are contained in a housing at the base of the pump casting, which is provided with a cover plate having a ground face, allowing only sufficient clearance for lubrication. The centres of the two rotors are offset. The rotor shaft is provided at its upper end with a recess which engages a projecting tongue on the lower end of the inclined driving shaft, that is itself driven by gears from the camshaft between the front two cylinders. The smaller rotor, by its engage-

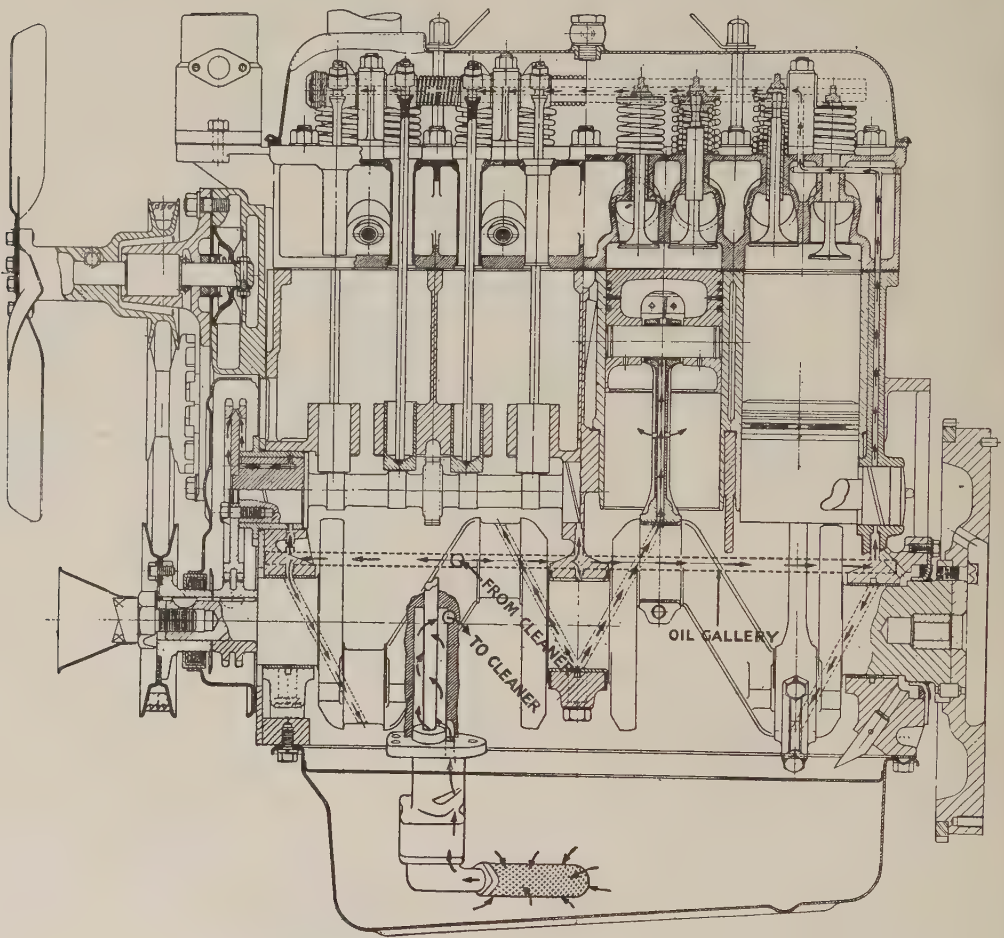


Fig. 498.—The Vanguard Lubrication System (Side Elevation).

ment with the outer rotor, drives the latter round at a slightly lower speed, and owing to the relative movement of the centre rotor around the outer one and the close fit of the cover plate, oil is forced round between the arms of the rotor and out of a hole in the top of the rotor casing; thence it flows upwards through a drilled passage in an annular space round the distributor driving shaft. Oil is drawn into the pump through a primary gauze filter and then through a channel in the pump casing and, as previouslydescribed, to a hole in the rotor casing and thence through a hole in the cylinder block into an external cleaner. The oil on its way to the cleaner assembly passes a spring-loaded ball valve (pressure relief) which is set to allow an oil pressure of 40–60 lb. per sq. in. at normal engine speeds. The filtered oil passes to an oil gallery above the level of the crankshaft main bearings and thence to the three main bearings, and, by drilled passages in the crankshaft, to the big-end bearings.

A special feature of the lubrication system is the provision of *drilled connecting rods* to lead oil to the small end bushes and gudgeon pins (Fig. 497). A radial drilling on the engine thrust side of the connecting-rod bearing housings provides oil-jet lubrication to the cylinder walls. Three of the camshaft bearings are supplied with oil from the oil gallery. The other camshaft bearing, namely No. 3 from the front, receives oil from the oil gallery through a $\frac{3}{32}$-in. restriction. A by-pass from the rear camshaft bearing conveys oil to the overhead hollow rocker shaft, and thence through radial holes to the rockers, leaving each rocker by a hole in its upper face, to cast ducts and then to the ball pins, push rods, and tappets. The timing chain is lubricated from the front camshaft bearing by 90° slots. The underside of the timing chain is lubricated by centrifugal action of the oil from the timing wheel.

Commercial-engine Lubricating Systems

The Austin commercial-vehicle[1] engine-lubricating system is illustrated in Figs. 499 and 500. The figures on these diagrams illustrate the sequence in numerical order, commencing with (1) of the oil circulation. The almost vertical drive to the oil pump (1) is shown in Fig. 500. The gear-pump draws oil from the sump through a gauze strainer and delivers it to the oil gallery (6) whence it goes to the main bearings and hollow crank shaft and thence to the hollow camshaft and its bearings and camshaft drive chain.

The sump capacity is 11 pints.

There is an A.C. oil filter, seen in the upper left-hand portion of Fig. 499, through which the oil under delivery pressure from the pump flows *via* (4) and (5) and returns, in the filtered condition, to the left-hand (or rear) main bearing. A supply of oil for the overhead-valve gear bearings is taken *via* (12), (13), (14) and (15) and drains back through return passages to the sump at the base of the crankcase.

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[1] 3-ton, 2-ton, and Ambulance vehicles.

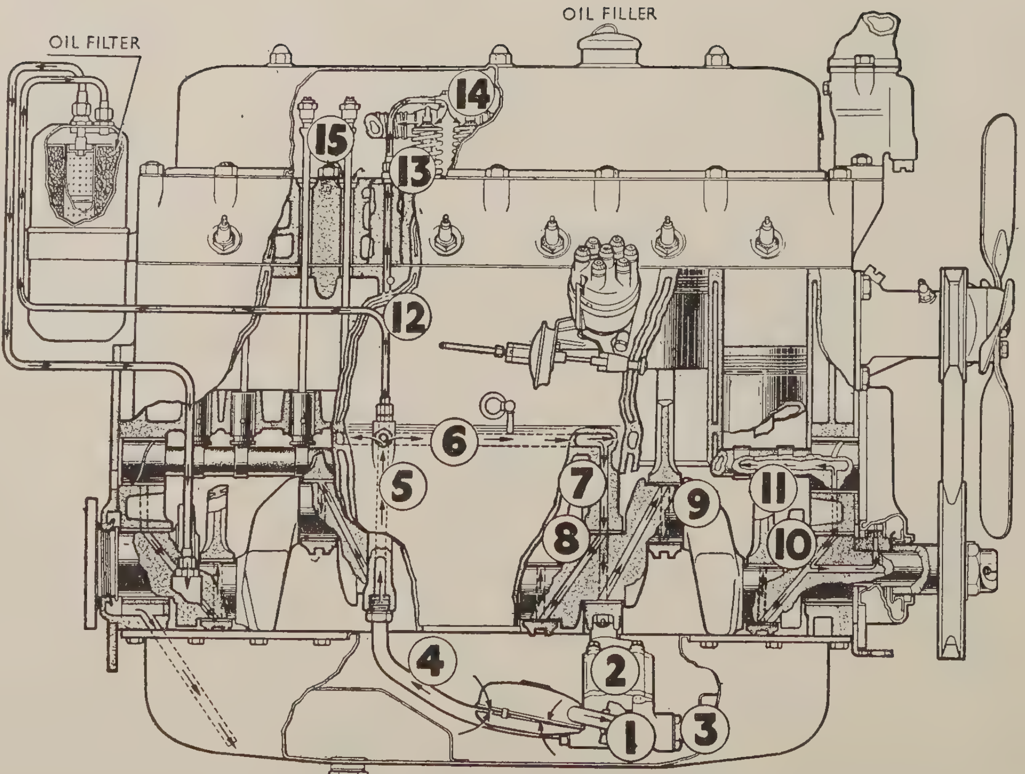


Fig. 499.—The Austin Commercial-vehicle Engine-lubrication System (Side Sectional View).

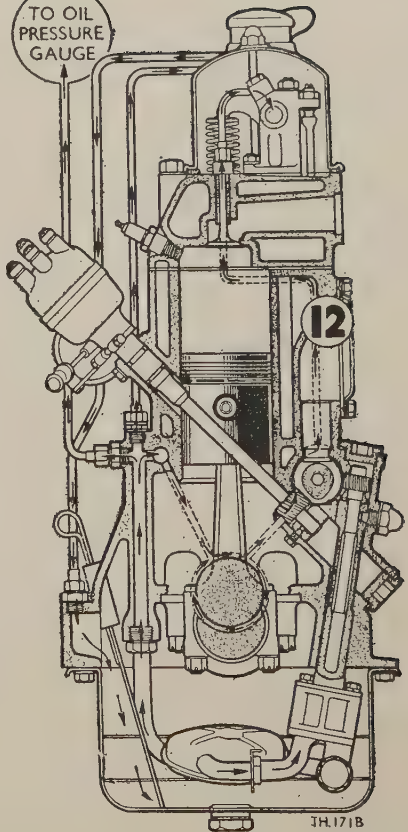


Fig. 500.—The Austin Engine-lubrication System (Front Sectional View).

There is a spring-loaded oil-pressure release valve on the delivery side of the oil pump. Surplus oil from this flows back into the sump.

At the front end of the crankshaft there is a bleed-hole to feed oil on to the camshaft chain. The cylinder bores are lubricated by small jets in the top of the upper half connecting-rod bearings

The oil filter which is bolted on to the rear of the cylinder head must be renewed, in regard to the felt filter element, every 6,000 miles.

The oil sump should be drained off every 3,000 miles and refilled with fresh oil. In the case of a new or reconditioned engine the oil should be drained at the end of the first 250 miles and again at 1,250 miles, when the engine is warm. The pressure-gauge reading when starting in cold weather should be about 40 lb. per sq. in., dropping to about 35 lb. per sq. in. when the engine reaches its working temperature.

Two types of oil pump are fitted to the Austin commercial-type engines, namely, the two-piece and three-piece models.

Fig. 501 illustrates the two-piece pump, in dismantled form, and it shows the skew bevel drive shaft operated off the camshaft—which has a similar gear. The oil-pressure release valve and the large-capacity strainer on the suction side of the pump are shown.

The pump is removed by first taking off the sump and disconnecting the oil-supply pipe from the pump body and crankcase. From the rear side of the latter the oil-pump locating screw (Fig. 502) should be removed. When the locking cap is removed a screw-driver can be used on the screw itself; there is a fibre washer under the nut. The complete oil pump can then be drawn down out of the crankcase.

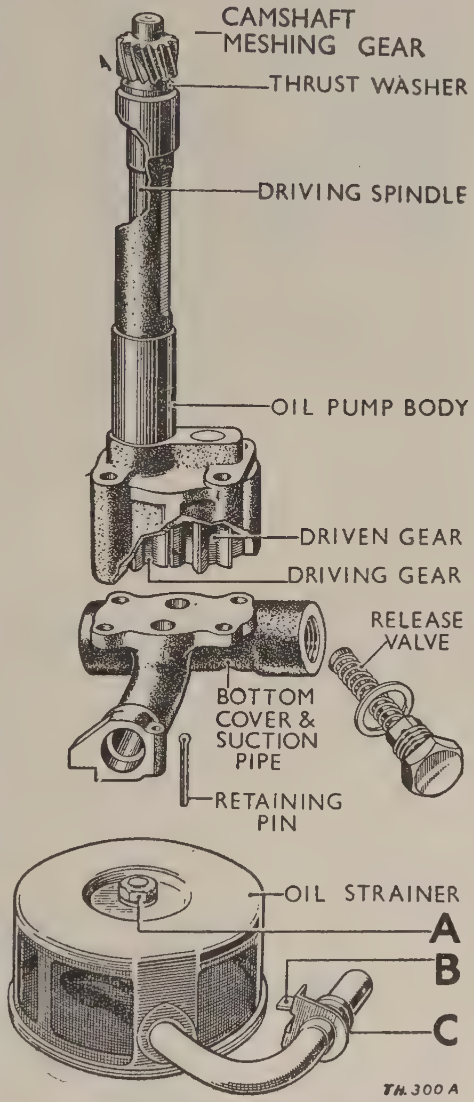


Fig. 501.—The Austin Two-piece Oil Pump.

When the pump is replaced it does not require to be primed with oil. The strainer is secured to the pump body by a cotter pin. It should be cleaned with paraffin when the pump has been removed, or otherwise when required. The strainer components securing nut is shown at A in

Fig. 501. B denotes a tag which forms part of the bracket and registers with the oil-pump body (shown to left of retaining pin) and it serves to keep the strainer rigid; when correctly fitted the strainer should be horizontal. C denotes the registering portion of the strainer pipe that fits in the hole in the pump body.

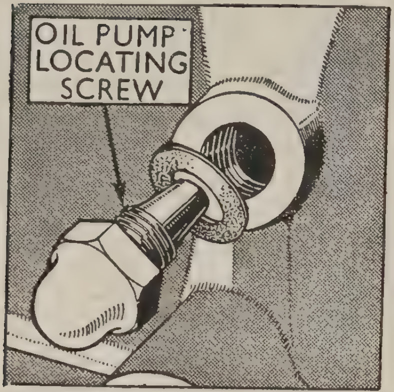


Fig. 502.

Fig. 503 illustrates the Leyland commercial-vehicle lubrication system used on the high-speed oil engines made by the firm in question. In this diagram the path of the flow is indicated by the black lines and white arrows.

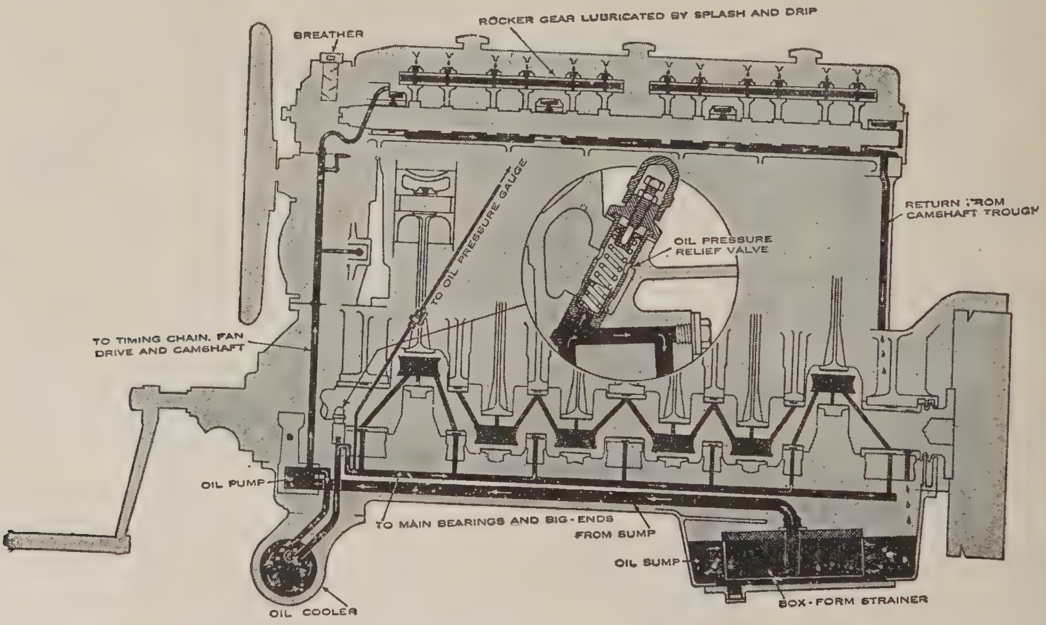

ROCKER GEAR LUBRICATED BY SPLASH AND DRIP
BREATHER
TO OIL PRESSURE GAUGE
RETURN FROM CAMSHAFT TROUGH
OIL PRESSURE RELIEF VALVE
TO TIMING CHAIN, FAN DRIVE AND CAMSHAFT
OIL PUMP
TO MAIN BEARINGS AND BIG-ENDS
FROM SUMP
OIL SUMP
BOX-FORM STRAINER
OIL COOLER

Fig. 503.—The Leyland Oil-engine Lubrication System.

The gear-wheel oil pump is situated at the front of the engine and placed above the level of the oil sump, on the lower right-hand side. The oil-suction pipe is provided with a cylindrical gauze filter. The oil drawn along the suction pipe by the pump is delivered to the oil cooler shown at the front, below; this reduces the oil temperature so that the oil has better lubrication qualities. The oil-pressure gauge and oil-release valve are situated on the delivery side; the latter is placed in an accessible position on the side of the crank-chamber. An enlarged view of this valve is given in the central circle. It will be observed that the plunger valve is spring-loaded, and is provided with a screw adjustment above; a lock-nut ensures that after adjustment the screw will not move.

Normally the oil passes below the valve, from left to right, as shown by the white arrows in both the smaller and larger views. Should the oil pressure increase above its pre-set value, the plunger valve is caused to lift and allows the pressure to fall.

The oil delivered past the pressure-release valve flows upwards to each of the seven main bearings (for the six-cylinder engine has a bearing on each side of each crank). The oil flow is shown by the white arrows just above the oil-suction pipe ones. From the main bearings the oil flows into the hollow crankshaft and along to the crank-pins and big-end bearings.

The overhead rocker arms are lubricated by a separate supply taken from the pump, up the vertical passage, shown on the left-hand side, whence it also lubricates the triple-roller chain for the timing gears, etc., the camshaft bearings and the radiator cooling-fan bearings. The oil-return shaft is shown on the right-hand side, the used oil flowing downwards and dripping into the oil sump.

This oil-return passage communicates with a trough running along below the rocker-arm bearings, as indicated by the black line and white arrows below the rocker gear.

The Dry-sump Method

In each of the previous lubrication systems described, the bulk of the oil is kept in the sump at the bottom of the crank-chamber and the oil pump draws its supply from this source. Unless, however, a separate oil cooler is provided, it is difficult to keep the temperature of the oil down to a satisfactory value for the most efficient results.

The dry-sump method obviates this difficulty by providing a second oil pump known as the *scavenging pump* to draw the oil out of the sump (which is then of smaller capacity) and to return it to a separate reservoir outside the engine, where it is cooled. The oil-pressure pump for circulating this oil is situated inside or on the side of the crankcase. The sump therefore remains practically empty, so that the engine can be tilted or rocked about without affecting the efficiency of the lubrication system. For this reason, the dry-sump method is employed chiefly in aeroplane and motor-cycle engines, although it is also to be found in some of the more expensive types of motor-car engines.

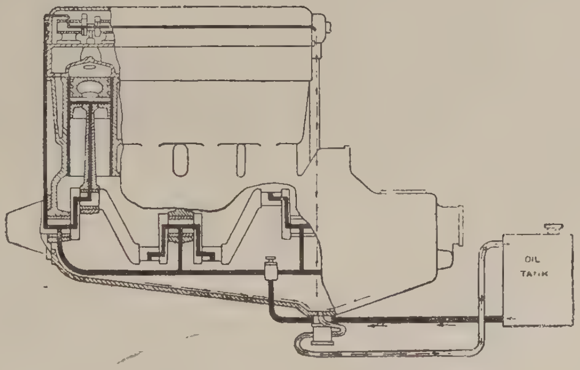


Fig. 504.—The Dry-sump Lubrication System.

Apart from the second "scavenging" pump and separate oil reservoir, the actual pressure lubrication system is identical with that of the wet-sump full-pressure system previously described. The oil, however, is kept cooler in its circulation and under better control in the dry-sump system.

In regard to the two pumps employed, the scavenging pump is the larger of the two, for it has to deal with larger quantities of oil at low-lift pressures, whereas the pressure pump deals with small quantities at high pressure.

The Oil Filler and Dip-stick

Fresh oil for filling or replenishing the oil sump is poured in through a filler orifice or tube having a dust-tight cover, which is removed when the oil is poured in. In the case of side-valve engines, the filler usually consists of a steel tube leading to the crankcase, and with its upper end placed conveniently for pouring in the oil. Overhead-valve engines generally have their oil fillers on top of the valve cover, and are therefore quite accessible. Gauze strainers are fitted, or should be fitted, to all oil fillers.

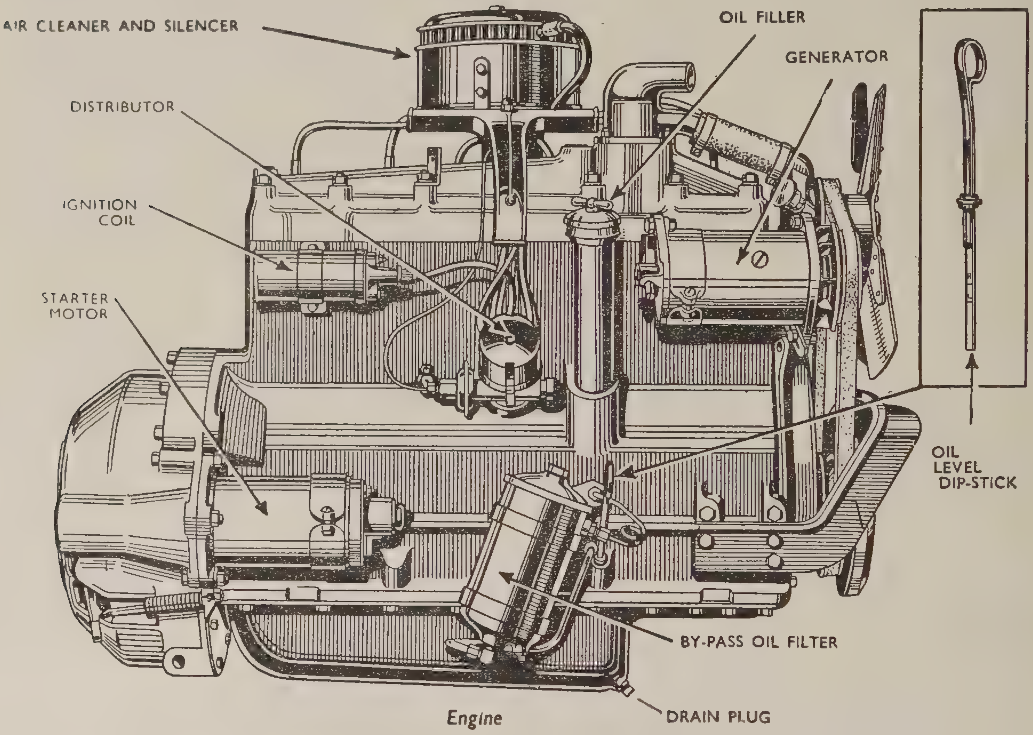


Fig. 505.—Showing External Features of the Humber Super-Snipe Engine Lubrication System.

When filling or topping up with fresh oil, allow sufficient time to elapse before taking the oil level by means of the dip-stick or oil-level gauge; the vehicle should be standing on level ground with the engine not running.

Fig. 505 shows the various external features on the off-side of the Humber

Super-Snipe engine. These include the screw-down cap-type oil filler, dip-stick, external by-pass type of oil filter, and the oil-sump drain plug (lower right side). In this example the oil level should be checked every 200 miles; the dip-stick should first be removed and wiped before actually measuring the oil level in the sump. The dip-stick is marked "High" and "Low," and the difference between these two levels is 2 pints of lubricant.

It is recommended that the oil be drained every 2,000 miles. This should be done when the engine is warm, i.e. soon after a run. The capacity of the oil sump is 14 pints. Other engine sump capacities are given in the Data Volume issued with this publication. The oil sump should, after draining, be thoroughly cleaned every 6,000 miles. This necessitates removal of the sump lower pan, which is held by 23 set-screws and spring washers. When the sump is removed it is important to *disconnect the oil-pump floating intake filter* from the engine and to clean this with paraffin.

The filter element in the oil system of any engine requires periodical cleaning or, after a certain mileage, replacement, as explained in the next section.

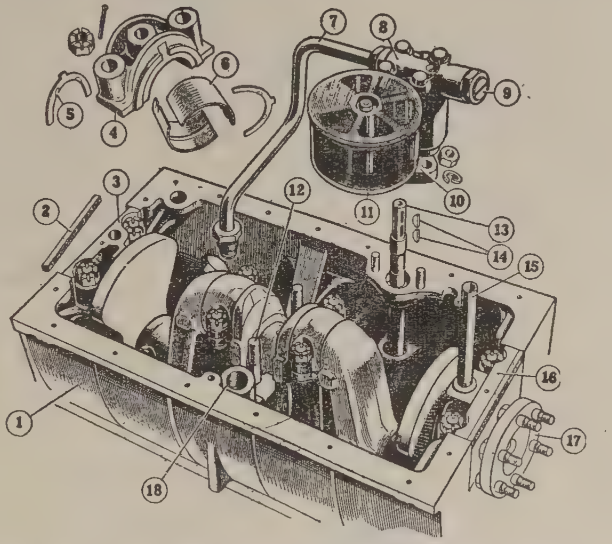


Fig. 506.—The Austin Engine, showing Crankcase, Bearings, and Oil Filter.

1, Crankcase. 2, Cork Insert. 3, Front Main-bearing Cap. 4, Centre Main-bearing Cap. 5, Thrust Washer. 6, Bearings. 7, Oil-delivery Pipe. 8 and 9, Pressure Relief-valve Unit. 10, Oil-pump Body. 11, Filter. 12, Main-bearing Stud. 13, Oil-pump Spindle. 14, Keys. 15, Rear Bearing Overflow. 16, Sump Joint. 17, Flywheel Coupling. 18, Oil-pump Housing.

The Oil Filter or Cleaner

The importance of maintaining the lubricating oil in a very clean condition is recognised by the modern car-engine manufacturer, as it is well known that the life of the bearings, cylinder walls, and other sliding surfaces can be extended considerably by keeping the oil thoroughly clean.

The modern lubrication system usually has two and sometimes three filtering devices. A typical example has a fine-gauze strainer around the oil-pump suction pipe, and an external—or accessible built-in—filter with a felt or multiple-plate filtering element. This filter is on the delivery side of the oil pump, and it usually incorporates an automatic relief valve such that, should the filter element become choked, the valve lifts and allows the unfiltered oil to flow to the normal cleaned oil outlet of the filter, thus ensuring engine lubrication, but with unfiltered oil. For this reason it is important to clean or change the filter element at the periods recommended by the manufacturer of the engine.

Two Types of External or Built-in Oil Filter

There are two principal types of oil filter of the pressure-fed kind, namely, (1) *the full-flow type*, and (2) *the by-pass type.*

(1) *The full-flow type of filter*—a typical example is that of the Morris Six engine shown in Fig. 507—is such that all of the lubricating oil, delivered under pressure direct from the oil pump, flows through this filter before it is delivered to the oil gallery or main bearings. Should the filter element become choked a pressure relief valve opens and the oil is then by-passed from the pump direct to the oil gallery and main bearings; this oil, it must be remembered, is no longer filtered, and if the filter element is not cleaned or changed damage may be done to the bearings and crank journals.

(2) *The by-pass filter* deals only with a certain proportion of the total oil delivered by the pump, the rest passing direct to the oil gallery and bearings. A typical example of a by-pass filter system is that used in the Austin A40 engine illustrated in Fig. 508.

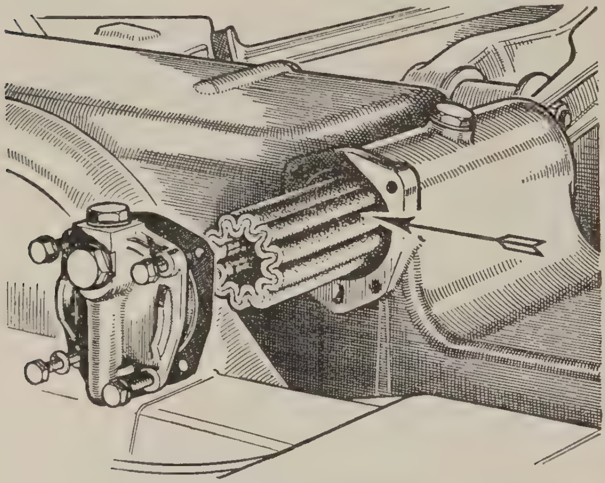


Fig. 507.—Morris Six Full-flow Filter (Arrow shows Filter Element).

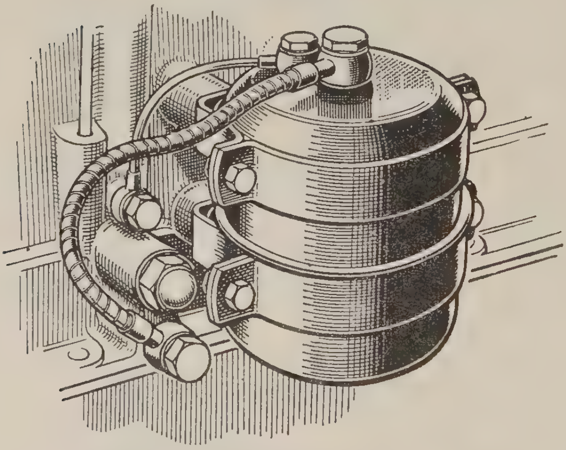


Fig. 508.—The Austin A40 By-pass Oil Filter.

In the Morris Six full-flow filter system the filter element is housed in a compartment on the lower side of the front end of the crankcase.

Fig. 507 shows how the cover of this compartment is removed for withdrawing the star-shaped felt filter element by unscrewing the four set-screws, seen on the right, in their holes in the cover.

When the filter element is removed, as it should be, every 3,000 miles it is cleaned in petrol to get rid of any sludge. At the same time the inside of the compartment should be washed out with paraffin. The balance valve is taken out of the filter cover to ensure that the plunger is quite free.

The filter element will last for 12,000 miles if cleaned at 3,000-mile intervals. At the end of the former period a new element must be fitted. Some makes of felt filter element are given a total life of about 6,000–8,000 miles, but in all cases the manufacturers' recommendations must be adhered to.

A typical by-pass filter, namely, the A.C. filter as fitted to the Humber Super-Snipe engine, is shown partly dismantled in Fig. 509. This filter deals with 10 per cent. of all the oil delivered by the oil pump, and after this by-passed oil is cleaned by the filter it is returned to the oil sump. Under normal conditions this filter will operate efficiently for 10,000 miles before the filter element requires renewal. Access to the filter element is gained by undoing the securing nut on the cap and lifting off the latter. Before a new element is fitted, the barrel should be cleaned with petrol, but before doing this the return pipe to the engine from the filter must be disconnected from the base of the latter, the sludge being washed out through the orifice in the base after the drain plug (shown below in Fig. 509) has been removed.

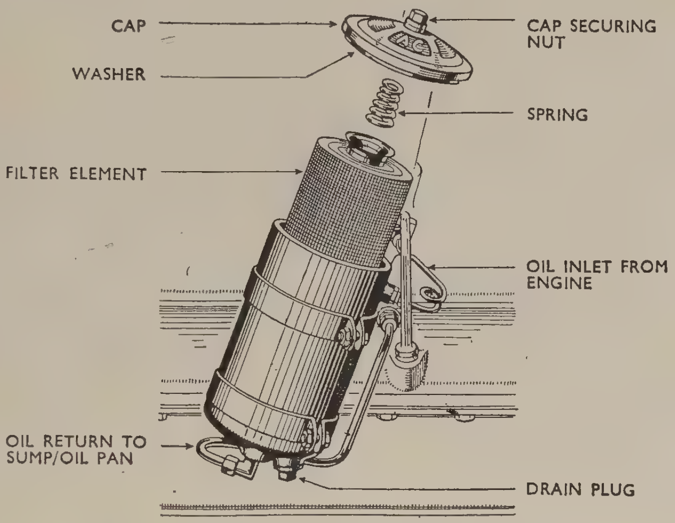


Fig. 509.—The Humber Super-Snipe By-pass Filter.

In the case of the Austin A40 external oil filter (Fig. 508), the cleaning element cannot be removed, as it is sealed into the casing. It is therefore necessary to remove the complete filter, by disconnecting the two oil-pipe unions and the four set-screws of the two securing clips. In the earlier model used on A40 engines copper pipes were used for the inlet and return, and there was some risk of fracturing these pipes when releasing the union nuts. In the later models a flexible oil-return pipe is used, so that this risk is obviated.

Oil Cooler and Filter Unit

In certain engines, notably those designed for long life and high operating efficiency, the hot engine oil that would normally drain back into the oil sump and be used again in its heated condition is delivered to a combined oil cooler and filter. The cooler has aluminium cooling fins or ribs, and

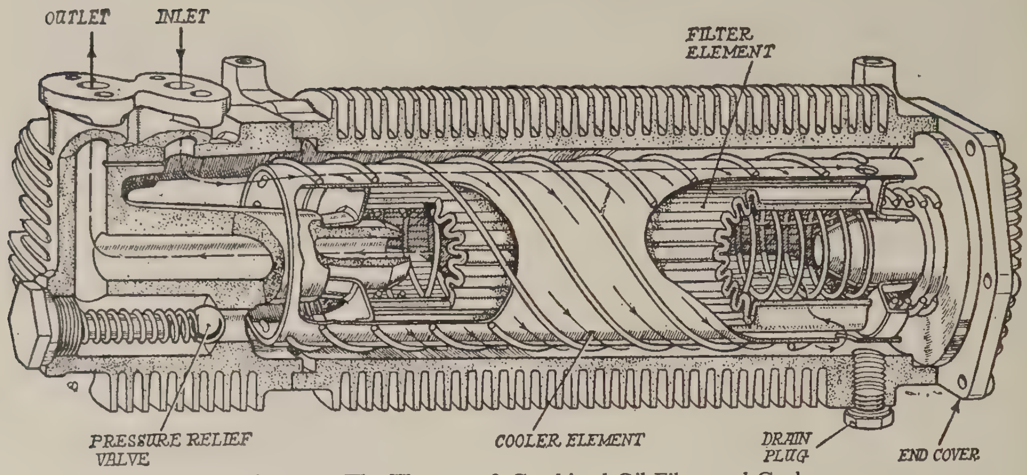


Fig. 510.—The Thornycroft Combined Oil Filter and Cooler.

after passing inside the finned or ribbed casing, the oil goes through the filter element and then on to the oil gallery, main bearings, etc.

Fig. 510 shows the oil cooler and filter used on the Thornycroft vehicle Diesel engines. The arrows indicate the oil circulation direction, and it will be seen that the oil flows spirally inside the finned aluminium casing before entering the filtering unit, through which it passes to the inside, and then from right to left on to the "Outlet." The oil cooler and filter unit is located at the bottom of the front or radiator end of the crankcase, and is readily accessible for cleaning or filter element renewal. The element should be cleaned every 2,000 miles and renewed at the end of 10,000 miles.

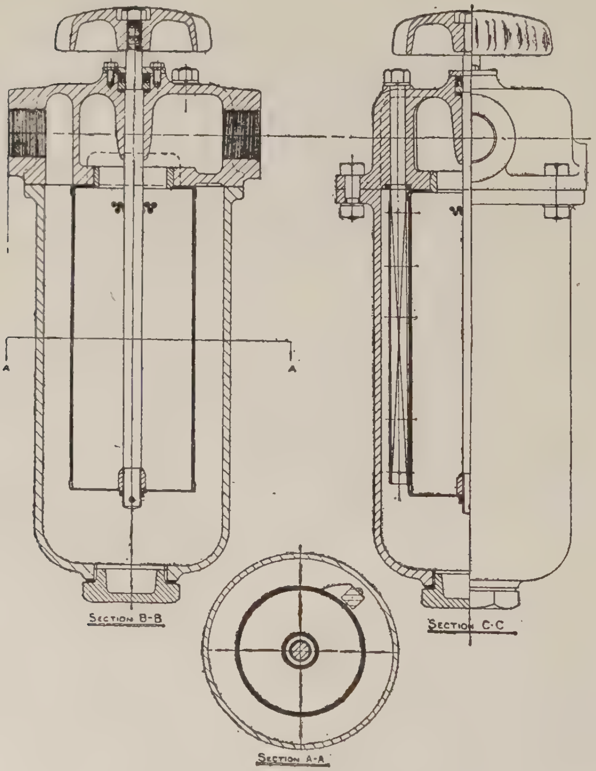


Fig. 511.—The Furolator Oil Filter.

The Purolator oil filter, which is fitted to certain makes of commercial-vehicle engines, is shown in Fig. 511. It employs a permanent metal filtering element consisting of specially shaped flat wires of brass, monel metal or stainless steel, arranged as shown in Fig. 512. The filtering wire has a taper cross-section with very small projections to separate the individual wires and thus leave extremely small spaces which trap the solid matter in the oil as it flows from outside to inside the filter. All of the solid matter is actually left on the outside of the cylindrical filter element formed by the continuous wire unit. Particles as small as ·0005 in. are thus prevented from passing through the element.

In order to clean the filter a fixed scraper is employed. The scraper consists of a springy bronze blade supported by a solid rod and the edge of the blade rests against the outside surface of the filter element, as shown in the plan view of Fig. 511. The latter is supported by a vertical shaft and can rotate in a fixed bearing in the top portion of the filter. A hand-operated knob (shown at the top in Fig. 511) enables the element to be rotated and the deposit scraped off, to fall to the bottom of the filter whence it is removed periodically by undoing the plug at the base. In some cases an oil-pressure release valve is provided to prevent excess pressure should the cleaning of the filter element be overlooked.

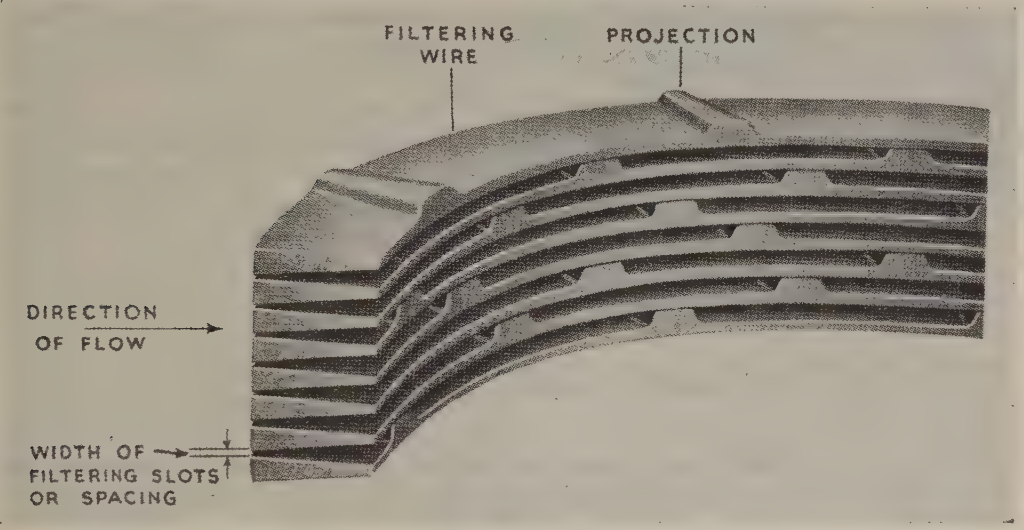


Fig. 512.—The Filter Element of the Purolator Oil Filter.

The knob on the filter should be given a turn about once every 1,000 to 2,000 miles.

Cleaning Felt Oil Filters

Felt oil filters of the Tecalemit and similar types are cleaned by immersing and agitating them in a bath of petrol. This cleaning process should be done at regular intervals of 2,000 to 3,000 miles.

At the end of 8,000 to 10,000 miles, the filter element should be removed and replaced with a new one; the latter is quite cheap and readily fitted into place. It is inadvisable to use the same filter indefinitely, since its cleansing properties, despite frequent cleaning in petrol, definitely deteriorate.

Fig. 513 illustrates a felt-pattern oil cleaner used on some of the A.E.C. oil engines.

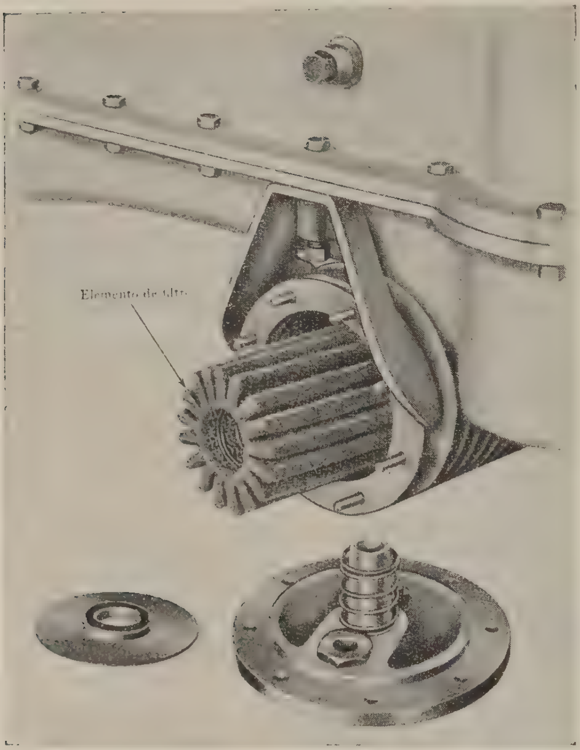


Fig. 513.—Felt Filtering Element used on certain A.E.C. Oil Engines. The Cover is shown removed.

Oil-gauge Readings

Although in the case of low-pressure lubricating systems the oil gauge is used principally as an indicator to show that the oil sump is working, with the higher pressure system the *actual readings* of the pressure gauge must always be taken into consideration when checking the working of the oiling system. *When the engine is cold* and is first started up, the oil is much heavier, or viscous, so that the pump has to exert a higher pressure on it to force it through the oil pipes and passages owing to the greater frictional resistance. For this reason, most pressure gauges read high when the engine is started from the cold, but as soon as the oil becomes warmed the pressure drops to its normal reading. Thus, with certain Morris car engines the pressure gauges read from 50 to 60 lb. per sq. in. when engines have been started from the cold, but when the engines have warmed up this pressure falls to 30 to 40 lb. per sq. in.

It is usual to specify the top-gear car speed at which the correct oil pressure should be obtained. Thus in the Wolseley Six-Eighty engine the correct oil pressure is 40 lb. per sq. in. at 30 m.p.h.; above this speed the oil pressure increases slowly.

For the Austin A40 engine the normal running pressure is 25–30 lb. per sq. in. at 30–40 m.p.h., with lower pressures at slower speeds.

The Sunbeam Talbot 90 engine oil pressure is 45–50 lb. per sq. in. at 30–45 m.p.h. These are typical examples of modern engine oil pressures. If the oil gauge fails to show the value stipulated the engine should be stopped and the cause ascertained, as explained later.

Oil-pressure Warning Lamps

In certain motor vehicles, of which the Hillman Minx Mark IV and the Bedford K, M, and O are typical examples, instead of fitting an oil-pressure gauge an electric warning lamp, either green or red, is fitted to the instrument board. When the ignition is switched on, the light is also " on," and after the engine has been started and runs at a low speed the light continues to show. When the engine is accelerated and the oil pressure reaches a predetermined value the light goes out. The circuit for this lamp includes a live battery lead to a pair of contacts, one of which is actuated by the movement of a flexible metal diaphragm the other side of which is subjected to the pressure of oil in the lubrication system. When *the engine is at rest*, the two contacts are touching and the circuit is completed, so that the lamp is illuminated. When the oil pressure builds up to a certain value the contacts are separated, thus switching off the oil-pressure warning light. If *the light fails to go out*, this indicates that the *oil pressure is too low*; the engine must be stopped and the cause ascertained.

If the lamp *fails to illuminate* when the ignition is switched on, a faulty bulb or defect in the wiring is indicated. The trouble should be rectified as soon as possible; otherwise there is no means of ascertaining whether the oil pressure is satisfactory, and a ruined engine may result.

If the lamp is illuminated when the *vehicle turns a corner* and then goes out, this indicates too low an oil level in the sump.

Engine Lubrication and Maintenance

Since the general efficiency, reliability, and life of an automobile engine depend upon the satisfactory operation at all times of the lubricating system, the latter must always be maintained at its highest efficiency.

This maintenance attention must, of course, date from when the engine is new.

When the vehicle is received from the manufacturers it has a full supply of fresh oil in its sump. Since, however, all of the wearing surfaces have to become well " bedded down " during the first few hundred miles of the vehicle's life, there is always a possibility of solid matter finding its way into the oil from the metal surfaces, castings, etc., inside the engine when the latter is new.

It is always advisable, therefore, to *completely change the oil* after a new vehicle has done about 500 miles of road service.

Draining the Oil

The engine should be thoroughly warm before the oil is drained, since the oil is then in its " thinnest " condition and, therefore, easier to drain. The sump plug is removed, after placing a suitable receptacle below the sump to catch the oil. The oil, after flowing freely, will continue to drip for an hour or two, so that the process of draining should not be hurried. It is a good plan, after the oil has flowed out, to remove the sump and wash it in paraffin. *Do not*, however, *pour paraffin into the sump* through the oil filler in order to clean the sump, since there is a risk of some remaining and diluting the fresh oil and interfering with the action of the oil pump.

The engine oil should be drained off and discarded at the following intervals, commencing with the new engine: 500, 2,000, 4,000, 6,500, 9,000 miles, etc. Most manufacturers recommend the draining off of the oil every 2,000 to 3,000 miles after the first 500 miles. When draining the oil, give the starting handle a few turns now and again, to assist the draining operation.

In the case of engines which have been in service for an appreciable period, the oil should be changed more frequently, since there is a certain amount of dilution of the oil due to petrol condensation products from the combustion chamber which find their way past the piston during the compression stroke. The oil also becomes more contaminated with carbon from the burnt gases and burnt oil that finds its way into the combustion chamber; furthermore, dirt in the carburettor air is more liable to get past the piston. *Every time the lubricating oil is changed* the oil-filler filter and the oil-cleaner filter (gauze or felt) should be cleaned. Gauze filters are cleaned by washing in paraffin; felt filters, in petrol.

Never use cloth or rag to clean gauze filters, as small pieces of fluff or thread may become detached and eventually find their way into the oil passages, where their presence may cause trouble. It is advisable to use a bristle brush for cleaning the filter.

Oil-system Troubles their Causes

The lubrication system seldom gives trouble, but when this occurs it is usually difficult for the inexperienced operator to locate. For this reason the following notes on the chief causes of lubrication-system troubles should enable a fairly rapid diagnosis to be made in most cases:

Symptom No. 1. *Oil-pressure gauge shows no pressure when engine is running.*

Possible causes.

(*a*) No oil in the sump.
(*b*) Oil-gauge connection pipe bent, broken, or stopped up.
(*c*) Oil-release plunger or valve stuck open.
(*d*) Weak or broken oil-release valve spring.
(*e*) Pressure gauge defective.
(*f*) Oil pump not working through faulty valve, worn gears, or plunger, etc.

Symptom No. 2. *Oil-pressure gauge indicates low pressure.*

Possible causes.

(*a*) Oil-release valve not operating through faulty valve, valve seating, or spring.

(*b*) Oil-release valve adjustment set to too low an opening pressure.
(*c*) Leakage of oil from delivery (pressure) side of the oil system due to broken pipe, slack union, etc.
(*d*) Slack main bearings, allowing oil to escape. Slack big-end bearings will show similar effects.

Symptom No. 3. *Excessive oil pressure shown by gauge.*

Possible causes.

(*a*) Oil-gauge reading too high.
(*b*) Oil-release valve stuck or adjusted to too high an opening pressure.
(*c*) Too thick oil, or reading taken when engine is almost cold.
(*d*) Stoppage of oil channel or channels on pressure side of oil system, on other side of oil-gauge connection.

Symptom No. 4. *No oil passing to valve rockers.*

Possible causes.

Restriction or stoppage in tube to crankcase. Broken pipe on union causing leakage between pump and rocker bearing.

External Symptoms of Lubrication Trouble

Occasionally an external examination of the engine will reveal, by the presence of oil which has leaked from an external oil pipe, pressure-gauge pipe, valve timing-gear cover, clutch casing, etc., the cause of excessive oil consumption or low oil pressure.

The exhaust gases should be examined for signs of blue smoke in cases where excessive oil consumption occurs. If this smoke occurs when the engine is accelerated, or after the engine has been "coasted" down a hill and then opened up again at the bottom, this is a sign of worn piston rings or cylinder walls.

In some instances, however, when the engine has been started from the cold and is warming up at a low engine speed, a thin blue smoke will issue from the exhaust. If the pistons and cylinders are in good condition this smoke will cease as soon as the engine is thoroughly warmed up.

In cases where an external oil-delivery pipe from the oil pump is arranged, the action of the latter may be checked by unscrewing one of the delivery-side unions and observing whether the oil flows regularly when the engine is run for a few moments.

Choice of Lubricating Oils

The lubricating system ensures a satisfactory supply of oil to the bearings and other working surfaces of the engine, but this in itself is insufficient unless the correct grade of lubricating oil is also employed.

No matter how thoroughly the oil is circulated through the engine, if the oil has inferior lubricating properties the engine will either wear more rapidly or eventually break down on account of inadequate lubrication to one or other of the working components.

The choice of a suitable lubricant for any particular engine is by no means a simple matter, for it depends largely upon the design of the engine, the working temperatures, pressures, and engine speed.

The metal surfaces of the cylinders and pistons are heated to a considerable degree during the explosion and expansion strokes; frequently the exhaust valve operates at a red heat. The explosion pressures—which are communicated to the cylinder walls, connecting rod, and main bearings—are high, being of the order of 450 to 600 lb. per sq. in. The lubricating oil must therefore withstand continuously the effects of these high temperatures and pressures.

In order to prevent seizure of the rubbing surfaces, e.g. the pistons and cylinder walls, it is necessary to maintain a layer of oil between the surfaces. This oil layer prevents metallic contact, and also reduces very considerably the friction between the two surfaces. Moreover, the load between the two bearing surfaces is " cushioned " by this oil layer.

The layer itself is generally extremely thin, being of the order of one- to three-thousandths of an inch.

Despite its very thin nature, it consists of three distinct layers, namely, a layer clinging to the fixed bearing member's surface, another layer clinging to and moving with the other moving bearing member's surface, and a third layer between the other two. The central layer consists of particles of oil which are being continuously sheared away from one another and united again while the moving member is in motion.

Now, the thinner the oil film between the fixed and moving parts, the greater will be the tendency for it to be forced out under the working pressures.

An inferior oil will become very thin at the working temperatures of the engine and thus tend to allow the metallic surfaces to come into contact and quickly " seize."

A thicker oil could be used, but if sufficiently viscous at the high working temperatures, would usually be too thick under the cold-starting conditions; moreover, the engine would not operate so efficiently, owing to the increased resistance due to the thicker oil.

Modern Engine Oils

There have been many developments in engine lubricating oils in the past few years, and most of the earlier problems connected with unsuitable viscosity which range over the working temperatures, carbon formation, sludge formation, and corrosion of the bearing surfaces, have now been solved or the actual conditions are known and suitable operating condition remedies made available.

The modern engine oil, of which Mobiloil may be cited as a good example, has three important properties that inevitably lead to longer cylinder-wall and piston-ring life, better bearing protection, improved engine performance, and easier cold-weather starting. These properties are as follows: (1) increased anti-acid quality; (2) higher viscosity index; and (3) greater detergency.

The viscosity index is a measure for indicating the rate of change in oil viscosity with changing temperature. A high viscosity index ensures easy cold-weather starting combined with excellent hot-engine lubrication.

An engine oil having good anti-acid properties prevents, largely, the oxidation of the oil under operating conditions; this is the cause of lacquer and sludge formation as well as corrosion of some bearing metals.

An oil having good detergent qualities is one that prevents the formation of deposits in the oil from causes such as rich mixtures, mineral and other fine deposits that become suspended in the oil. An interesting quality of a good detergent oil is that it has a *mild cleaning effect upon carbon or gummy deposits* behind piston rings, inside the pistons, on the piston skirts, valve mechanism, etc., so that in time these deposits gradually disappear and the working parts become much cleaner. Moreover, owing to freer piston-ring action the compression pressure is increased and the performance thereby improved.

There are, however, *commercial detergent oil solutions* which, when added to ordinary lubricating oils, bring about a similar cleaning action, but in a much shorter time; there is, however, a risk of the loosened deposits clogging gauze oil filters and oil passages in the lubrication system.

Upper-cylinder Oils

In the case of new and reconditioned engines which have had their cylinders rebored or new liners fitted, it is recommended that a small quantity of a special grade of lubricating oil known as *Upper-cylinder Lubricant* be mixed with the petrol supplied to the carburettor. This ensures that the upper parts of the cylinders and the inlet valve stems are adequately lubricated, more especially when starting from the cold.

With new engines, the rings and the pistons themselves are rather tighter, so that, until the surfaces are properly bedded in, it is advisable to provide adequate lubrication; it is chiefly on this account that upper-cylinder oil is recommended.

The usual proportions of these oils work out at about 1 egg-cupful per 2 gallons of petrol. In the case of Motorine U.C.L., 1 oz. per 2 gallons of petrol is recommended for new and rebored engines, and ½ oz. per 2 gallons for normal engines. Colloidal graphited oils now widely used for upper-cylinder lubrication are employed in the proportions of ½ oz. per 2 gallons.

Running-in New Engines

New and reconditioned engines, as previously stated, benefit by the use of an upper-cylinder oil mixed with the petrol. In addition, it is frequently the practice to mix a colloidal graphite, such as Acheson's, with the main oil in the crankcase sump. The graphite is in the colloidal state, and therefore microscopically fine, diffusing readily with the engine oil. It finds its way into the fine pores of the bearing-metal surfaces and tends to produce smoother surfaces on the bearing components. The results of scientific tests have shown that lubricating oil containing colloidal graphite reduces the friction by about 15 per cent. and produces on the various bearing surfaces a kind of graphoid surface, such that, should the oil film be broken owing to bad treatment of the engine, the bearing will continue to run without undue heating until the oil film is again restored.

Colloidal graphite is also suitable for stiff engines, as it tends to reduce the surface friction much sooner than by any pure attrition or " wear" method. In the case of tool-marked surfaces, such as cylinders which have been bored with a tungsten-carbide cutter, the graphite finds its way into the surface depressions and ultimately forms a practically continuous surface of low frictional resistance.

The usual proportions are *one pint of colloidal graphite compound to each gallon of lubricating oil in the sump.* At the end of the 500-mile running-in period this quantity may be reduced to half a pint per gallon.

CHAPTER 14

THE COOLING SYSTEM

Some General Considerations

THE cooling system of the modern car or vehicle engine consists of the radiator water-cooling spaces around the cylinder barrels and combustion heads, the flexible hose connections at the bottom and top of the radiator, the water circulating pump or impeller, the thermostat, and the engine-driven fan for drawing cool air through the fine air spaces of the radiator.

The circulation of the water in the case of the Austin 2-ton truck engine is shown by the arrows in Fig. 514. This vehicle has a cooling system comprising a water centrifugal pump and thermostat, both of which are shown to the left of the cylinder block in Fig. 514.

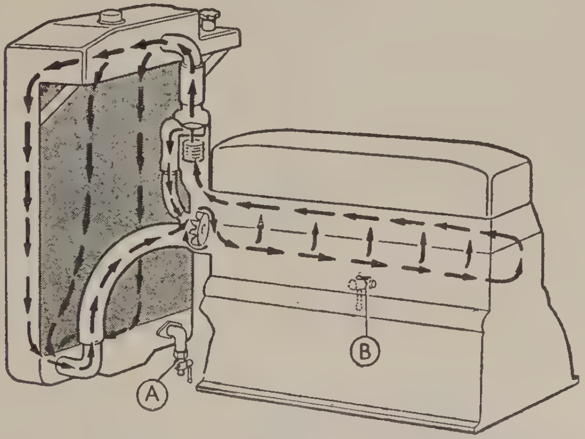


Fig. 514.—Water Circulation System of Austin 2-ton Vehicle Engine. (A) and (B) denote Drain Taps.

In vehicle cooling systems it is necessary to be able to drain all of the water from the system for dismantling, repair, or frost-precaution reasons, so that *a drain tap* (*or taps*) must be fitted at the lowest places of the system. Usually two taps are fitted, namely, one at the bottom of the radiator and the other at the bottom of the cylinder-block water space (Fig. 514). If a centrifugal water pump is fitted on a level with the lower radiator hose, or if its casing cannot be drained effectively when the rest of the system is emptied of coolant, then a drain cock is fitted to the casing; otherwise the water in this casing may freeze solid, and when the engine is started again the pump impeller shaft may shear off.

The Austin engines have a *patented expansion chamber*, as shown in Fig. 515, to prevent the (usual) loss of cooling water when the system warms up.

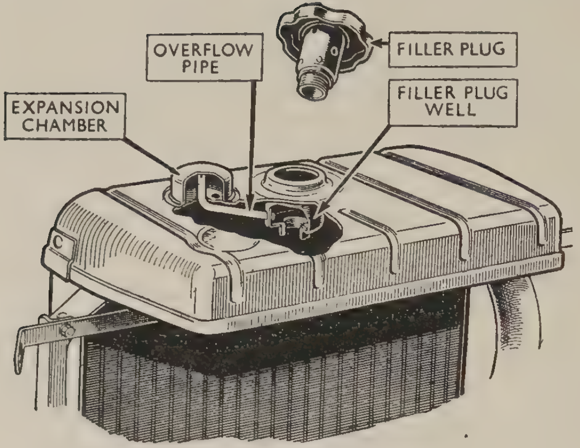


Fig. 515.—Radiator Expansion Chamber.

As the heated water expands it rises and fills the expansion chamber, whilst the displaced air escapes through a small overflow pipe connecting the expansion chamber to the bottom of the filler-plug well. Should further expansion occur water flows along the overflow pipe to the filler-plug well and is drawn back through the pipe into the radiator when the engine cools. With this design of radiator it is hardly ever necessary to " top up " the water for evaporation loss.

The Vauxhall Velox water circulation system is illustrated in Fig. 516,

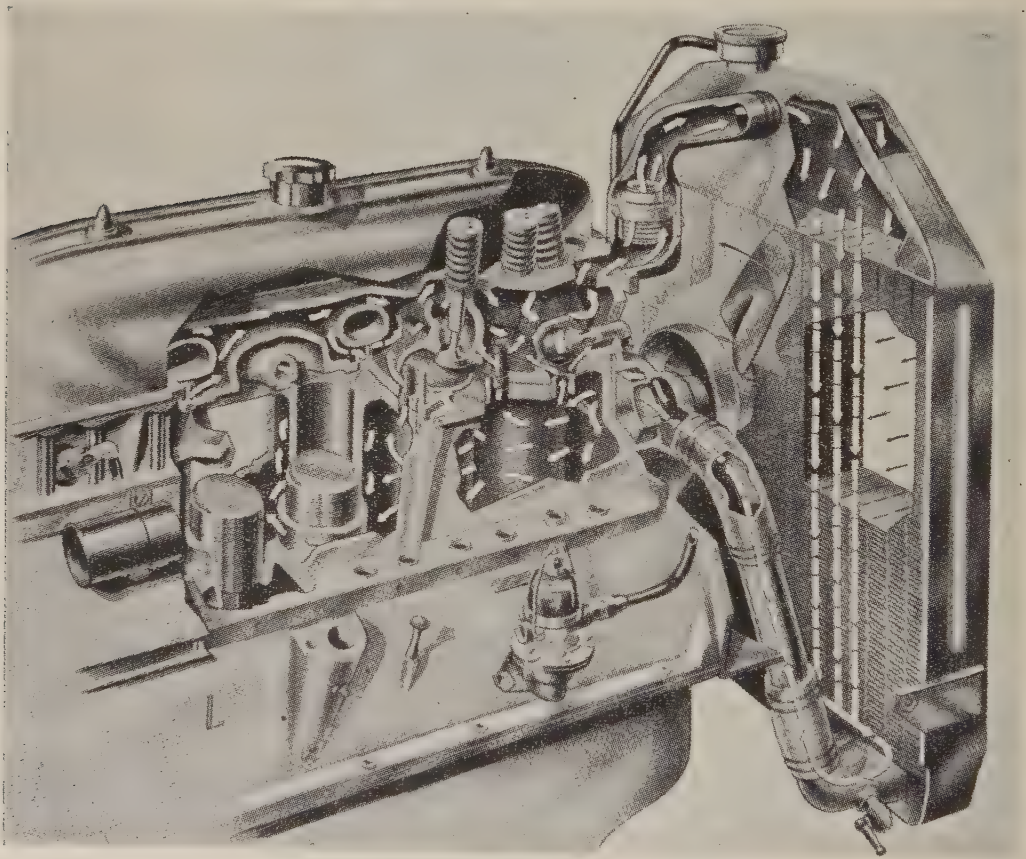


Fig. 516.—The Vauxhall Velox Water Circulation System.

the white arrows indicating the direction of the cooling water flow and the black arrows, on the right, the air flow through the radiator block. In this engine the two-bladed cooling fan shaft drives a water impeller, which forces the cooling water from the bottom of the radiator up the lower hose-pipe connection to a distribution tube located in the cylinder head, water discharge being directed adjacent to the exhaust-valve ports and sparking-plug bosses. The water then passes through the outlet pipe at the front of the cylinder head into the radiator top tank and down through the radiator to the bottom tank. There is a thermostat in the water-exit unit between the cylinder head and hose connection to the top of the radiator. This, as is explained in greater detail later in this chapter, maintains a fairly constant cooling water temperature, and provides rapid warming up from the cold.

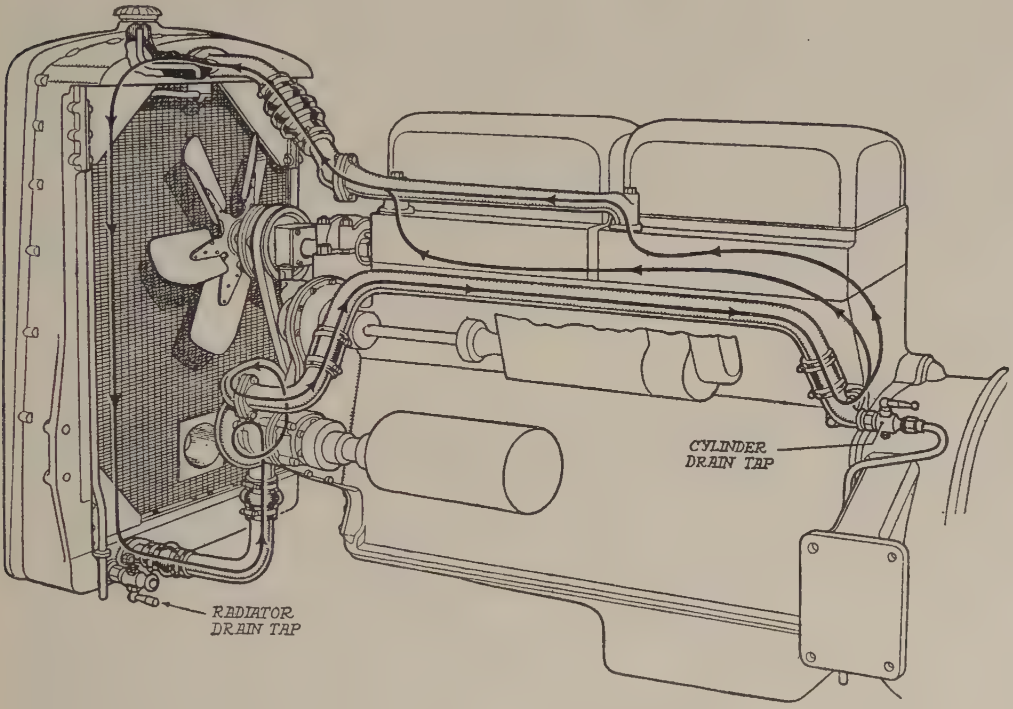


Fig. 517.—The Thornycroft Oil-engine Cooling System.

As an example of the cooling system of a large-type commercial vehicle engine, that of the *Thornycroft Trusty* heavy goods oil-engine vehicle has been selected, and its layout is shown diagrammatically in Fig. 517. The directions of water flow are indicated by the black arrowed lines. The cooling system comprises a Morris-tube block radiator, a water-circulating pump mounted on the front of the chain case cover, a water inlet pipe, the water-cooling spaces of the cylinder block and heads, and a water-outlet pipe. A six-bladed fan is belt driven from a pulley on the camshaft.

The radiator, with its Morris B-type block, has five rows of 36 brass tubes which have nine copper gills to the inch. The side columns are fixed to the top and bottom tanks and form the shape of the radiator. A grille is fitted at the front of the block and between the side members. The whole assembly is resiliently mounted on the front cross member of the chassis frame.

Removal of the Radiator

The modern car radiator is protected by an ornamental chromium-plated grille which serves to protect the more delicate thin-metal elements of the radiator cooling block from stones thrown up by vehicles ahead of the car. Before the radiator can be removed this grille must first be taken off. The actual method of doing this operation depends upon the type of car, so that no general instructions applicable to all cars can here be given, but one or two typical examples will be considered.

The Morris Oxford radiator removal procedure is as follows:

First raise the bonnet and engage the bonnet prop securely.

Drain the cooling system by means of the drain tap located under the bumper on the left side, and the tap on the left at the rear of the cylinder block. Remove the split pin locating the bonnet catch release rod to the bell-crank lever.

Release the clips from the top and bottom radiator hoses and remove the latter. Remove the four ¼-in. nuts with spring washers securing the radiator grille to the top rail and the nut and spring washer, second from the bottom, on each wing valance. The grille is then free to be withdrawn, but care must be taken not to lose the distance-piece tubes fitted to the bottom studs.

Release the five ¼-in. nuts with spring washers securing each radiator side plate to the wing valance.

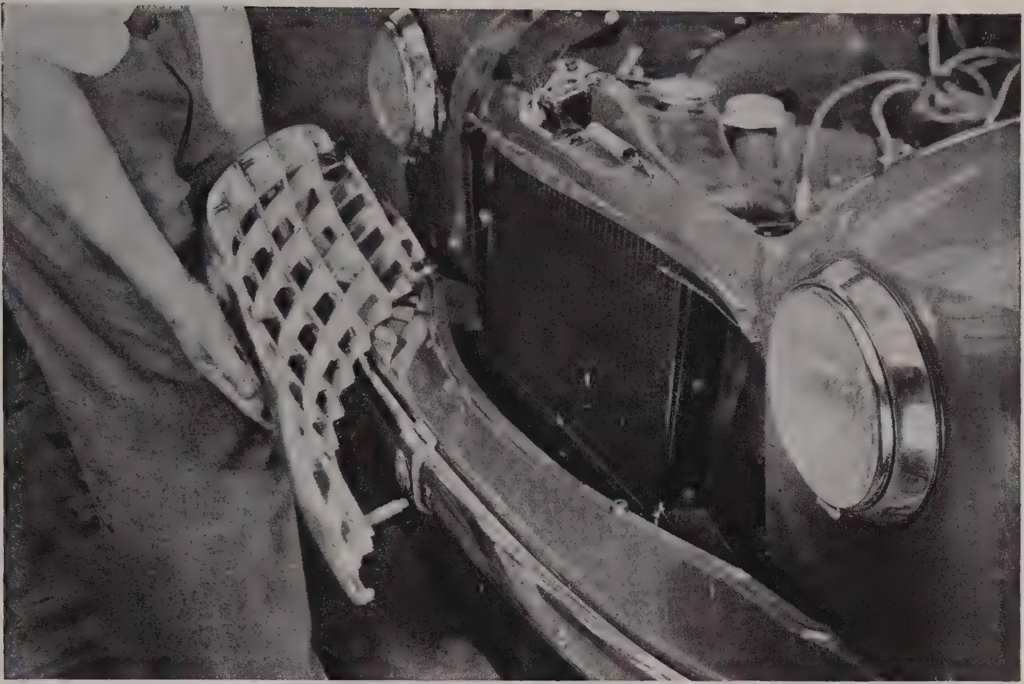
Withdraw the radiator together with its side plates, noting the positions of the flat packing washers.

It is recommended that the radiator, after removal, should not be laid flat, or inverted, since this will allow any accumulated sediment in the bottom tank to pass into the fine water-cooling ducts and to clog these.

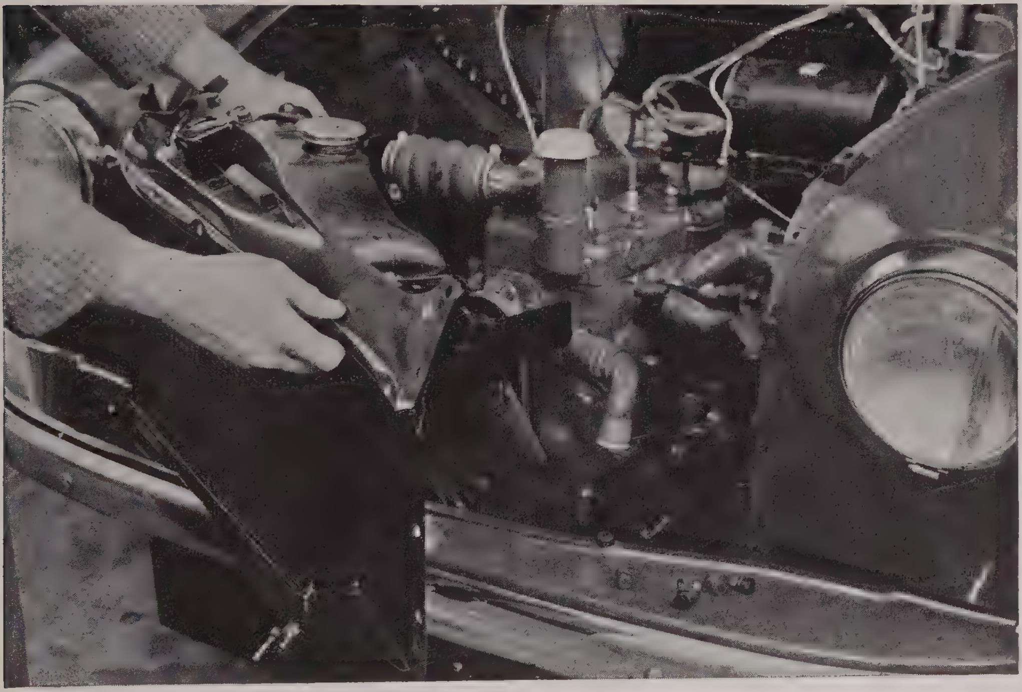
The Austin A40 radiator removal procedure is as follows:

Drain the cooling system by means of the drain taps on off-side of the cylinder block and that at the bottom of the radiator, noting that when the tap lever is vertically downwards *the tap is closed.*

Next disconnect the water hose at the top and bottom of the radiator block. The latter is held to the supports by three bolts, nuts and spring washers on each side, as shown in Fig. 518. Remove these; it will be found that the bottom bolt on each side will need a box spanner with a long tommy bar. The radiator block can now be lifted clear, tilting it towards the front of the car to facilitate this, and taking care not to damage the fins in the process.



REMOVAL OF MORRIS OXFORD (SERIES MO) RADIATOR. (1) TAKING OFF THE RADIATOR GRILLE, BEING CAREFUL NOT TO LOSE BOTTOM STUD DISTANCE TUBES.



REMOVAL OF MORRIS OXFORD (SERIES MO) RADIATOR. (2) REMOVING THE RADIATOR AFTER WITHDRAWING ITS TEN ATTACHMENT BOLTS.

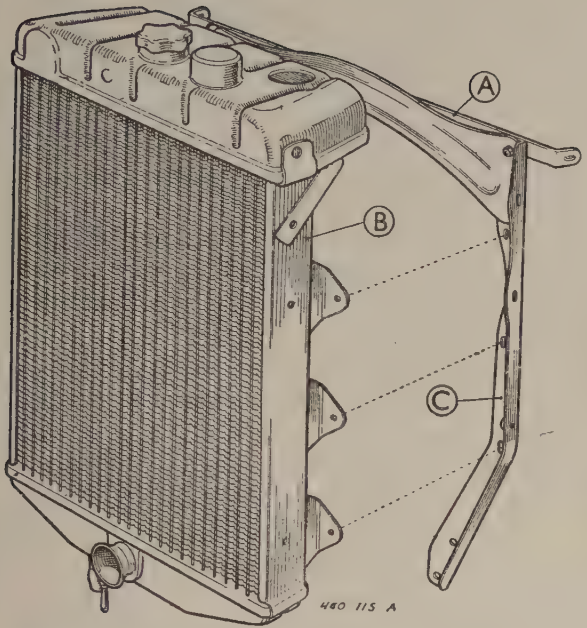


Fig. 518.—The Austin A40 Radiator and its Support. A—Mudwing Strut. B—Radiator. C—Combined Vertical and Horizontal Supports.

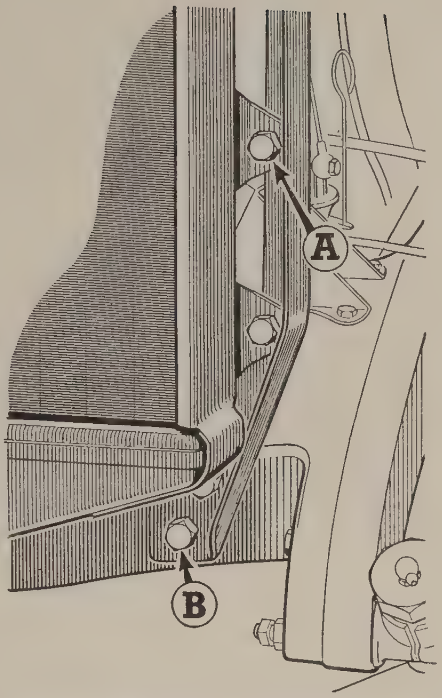


Fig. 519.—Attachment of Radiator Supports. A—To Radiator. B—To Frame.

The *radiator supports* (Fig. 519) are held to the front cross member of the chassis by two set-pins at each side and three bolts and nuts each side to the flitch plate. It is not necessary to remove these unless the engine and gearbox combined have to be removed from the chassis.

In connection with the A40 radiator grille, the top half is integral with the bonnet and is therefore lifted up with the latter.

As a final example of radiator removal and dismantling, that of the Thornycroft Trusty Oil-engine vehicle will be considered. The general layout of the cooling system has already been described, and is shown in Fig. 517.

The radiator mounting is of the flexible rubber kind, and is partly shown in section in Fig. 520.

The following are the detailed steps that should be followed in regard to the removal and fitting of the radiator:

Drain the cooling system.

Make up a lifting device by attaching a stirrup (the legs of which are approximately $3\frac{3}{4}$ in. apart) to a steel plate (about $\frac{1}{8}$ in. thick), in which a $2\frac{9}{16}$-in. hole has been made between the legs of the stirrup.

Fit the filler cap to the radiator with the plate of the lifting device in the place of the rubber joint (i.e. between the filler cap and the radiator).

It is essential that the plate is only little more or no thicker than

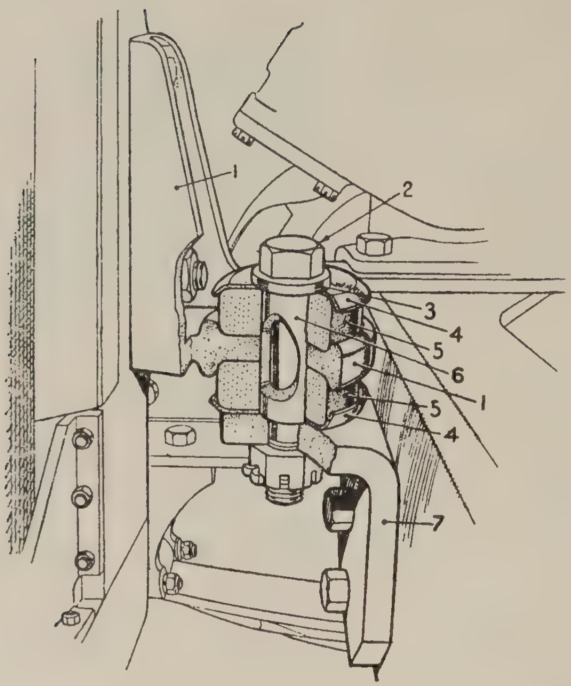


Fig. 520.—The Thornycroft Trusty Radiator Mounting.
1. Radiator Support Bracket. 2. Bolt. 3. Washer. 4. Cap. 5. Rubber Pads. 6. Distance Tube. 7. Radiator Support Bracket.

$\frac{1}{8}$ in., and that the filler plug is screwed home, otherwise insufficient thread will be screwed in the radiator to carry the weight safely.

Insert the hook of a crane or sling in the stirrup and take the weight.

Remove bonnet side panel.

Unscrew the clips at the top and bottom water-pipe hose connections.

Remove the $\frac{7}{16}$-in. slotted nut and pin from the jaw at the forward end of the tie rod.

Remove the four $\frac{7}{16}$-in. nuts and bolts which hold the two radiator support brackets on to the front cross member.

Pull the radiator forward, taking care not to let it swing (especially on overseas models, where a cowl having small clearance with the fan is fitted), lower it, and lay front downwards on suitable packing.

To fit the radiator, reverse the sequence of instructions for removal.

To dismantle and assemble the radiator:

Remove the radiator.

Remove eight screws and lift the grille away from the front of the radiator.

At the rear of the radiator, unscrew the twenty-four $\frac{5}{16}$-in. studs and remove the four gussets.

Remove the external overflow pipe by unscrewing the two $\frac{1}{4}$-in. nuts at the flange on the top tank.

To remove the top tank, unscrew twenty $\frac{1}{4}$-in. nuts, collect the shakeproof washers, and remove the four stiffening strips. Remove the four $\frac{7}{16}$-in. side-column nuts and washers, detach and clean out the tank, and clean the joint faces of the tank and tube plate and renew the joint.

The studs for the side columns will still be in the top tank and the top water pipe will still be attached. Remove the flange nuts and detach the top water pipe. Renew the flange joint and filler-cap washer if damaged.

Remove the bottom tank by removing twenty $\frac{1}{4}$-in. nuts and washers, four stiffening strips and four $\frac{7}{16}$-in. nuts and washers, clean the tank and joint faces. Renew the joint.

The removal of the top and bottom tanks releases the side columns and leaves the Morris-tube block free of all fittings.

Carefully examine the tube block for damage, and, if possible, repair where necessary.

To assemble the radiator, reverse the sequence of dismantling operations.

Dismantling Other Types of Radiator

From the preceding typical examples, some idea of the procedure for removing and dismantling radiators will have been obtained. In other cases it is advisable first to make a careful inspection to ascertain the method of fixing the radiator and also staying it to the frame or dashboard, when the method of its removal should be indicated. The bonnet and grille should usually be removed, but not always. The cooling system must be drained and the upper and lower radiator hose connections taken off. Finally, the radiator-block securing bolts or set-screws should be removed.

Maintenance of Radiators

Motor-car radiators require very little attention in the matter of maintenance, and if periodically attended to will seldom be found to give any trouble.

The water-pipe clips should be kept tight by means of the screws provided for this purpose. Every 1,000 miles or so of running, these screws should be tested for tightness with a screw-driver.

The radiator fins must be kept clean; any embedded matter, e.g. stones or insects, should be carefully cleared away.

In the case of engines having cast-iron cylinders and heads, every 5,000 miles wash out the complete cooling system with hot soda solution. The latter may be made by adding one half-pound of ordinary washing soda to two gallons of water. After this washing process, fill with rain water and then drain out. If a hose-pipe is available arrange for a supply of water from this to the top of radiator through the filler cap, and leave the drain-pipe open at the bottom so that the water will flow right through the system for 5 to 10 minutes.

When flushing through the cooling system with clean water with the drain taps open, the process should be continued until the water issuing is quite clean.

The cylinder block and head should also be flushed out until the issuing water is clean.

Reverse Flushing of Cooling System

It is a good plan to flush the cooling system in the opposite direction to that previously mentioned, by applying the flushing water to the lower hose connection for the radiator and the water jacket. This reverse flushing will dislodge any sediment in the radiator water spaces and water jackets (from the base regions).

Before the cooling system is filled with antifreeze solution and after the removal of the latter, the reverse flushing method should be employed. It is advisable to reverse flush all motor-vehicle cooling systems every 5,000 miles or so to ensure efficient cooling of the engine. The Vauxhall Motor Co., Ltd., recommend for the best results from reverse flushing the introduction of *water and compressed air* into the cooling system with the aid of a special flushing gun that is provided for use on their cars and commercial vehicle engine cooling systems.

Corrosion Inhibitor

After flushing out cast-iron heads and cylinders a small quantity of a proprietary make of corrosion-inhibitor fluid should be added to the cooling water left in the system. This mixes with the water and leaves an anti-rust film on the internal surfaces. About ½ pint of inhibitor for a 4-gallon-capacity system should be used.

Cooling Systems with Aluminium Parts

In the case of engines fitted either with aluminium cylinder blocks or heads, or with any other aluminium-alloy parts in the cooling system, the instructions given for the *use of soda solution do not apply*, since alkali solutions have a chemical action on aluminium and many of its alloys.

It is desirable to use either rain water or softened domestic water, in order to avoid the solid deposits from the untreated domestic water supply, for filling the cooling system. Whilst it is true that none of these waters is absolutely immune from corrosion tendency, this is minimised with rain or soft water.

The important point to observe when ordinary tap water is employed is to prevent the water from boiling in the cooling system, since solid matter, or salts, are precipitated under these conditions and tend to clog the radiator water spaces.

Anti-freeze Solutions

When certain chemicals are added to ordinary tap or rain water the freezing-point of the water (0° C. or 32° F.) is lowered by a certain amount or number of degrees, dependent upon the amount and nature of the additive.

Substances used for anti-freeze solutions include calcium salts, alcohol, glycerine and ethylene-glycol; the latter is the well-known aircraft-engine cooling-system coolant.

A mixture of 20 per cent. glycerine and 80 per cent. water lowers the freezing-point of water by 11° F.; 40 per cent. glycerine and 60 per cent.

water freezes at 0° F., i.e. lowers the freezing-point from 32° F. to 0° F. Glycerine was at one time used as an anti-freeze, but on account of the fact that it tended to attack the rubber hose connections and also due to a certain clogging effect in the radiator water channels, it has been discarded.

The most convenient anti-freeze available commercially is the ethylene-glycol one, of which "Bluecol," "Zero," and "Voco-Antifreeze" are typical proprietary products.

In these additives to water a small amount of corrosion inhibitor is included to obviate rusting effects.

The recommended Bluecol proportions are as follows:

Percentage of Bluecol	10	15	20
Equivalent quantity of Bluecol per gallon coolant (pints)	0·8	1·2	1·6
Actual Freezing-point	17° F. (−8° C.)	7° F. (−14° C.)	0° F. (−18° C.)

Bluecol and similar ethylene-glycol anti-freeze solutions do not evaporate, so that since it is only the water content that evaporates it is only necessary to add water to make up the correct strength of solution.

Using Anti-freeze Coolants

Before using anti-freeze liquids the cooling system should first be thoroughly flushed out with cold water and the cylinder-head nuts and water connections checked for tightness.

Care should be exercised in the selection of a suitable brand of anti-freeze, since cases have occurred in which unknown grades have caused serious corrosion of aluminium heads or have attacked the rubber hose connections. Only the well-established grades should therefore be employed.

It is advisable after filling a cooling system with anti-freeze solution to tie a label marked "Anti-Freeze" on the upper radiator hose or to pin it on the dashboard as a reminder to new drivers or garage hands that the system is filled with anti-freeze.

Radiator Tools and Equipment

Few automobile garages and repair shops are equipped with modern facilities necessary to do radiator repairing; consequently radiator repairs are done too frequently by improper methods and equipment. There is no difficulty in radiator repairing for any mechanic or automobile repairman who knows how to solder various metals. The equipment consists of a few soldering bits of different sizes and shapes (see Fig. 521), a gas stove or electric heater for heating them, wire and steel scrapers (a variety of scrapers can readily be made from old or worn files), air-acetylene torch or atmospheric gas blow-pipe (one which should furnish a fine needle flame), small hammer, wood mallet, wire scratch brush, tinsmith's snips, dent puller, pin, straightening tongs, pliers, soldering-flux receptacle, flux squirter or acid brush, repair bench, and water tank (Fig. 522), rubber testing plugs (see Fig. 523) (one each for filler cap, inlet, and outlet), rubber hose, movable light fittings (preferably electric), a small air compressor, air tank, and pressure gauge.

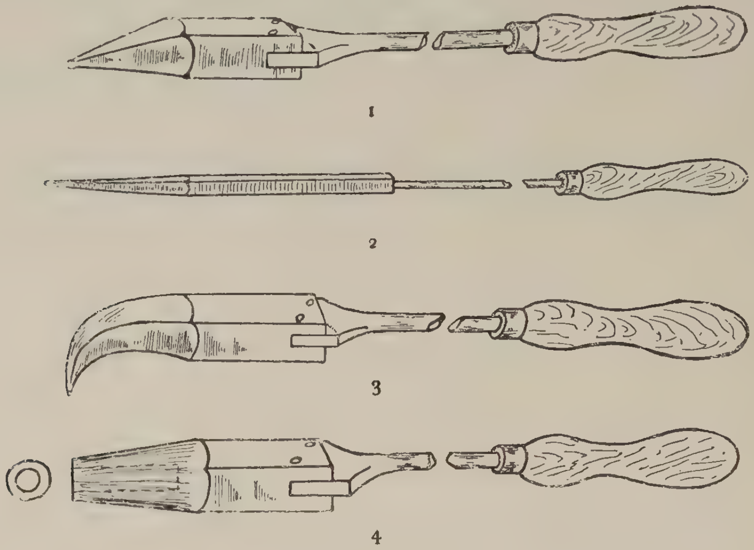


Fig. 521.—Radiator Tools. The uses of these are described later.

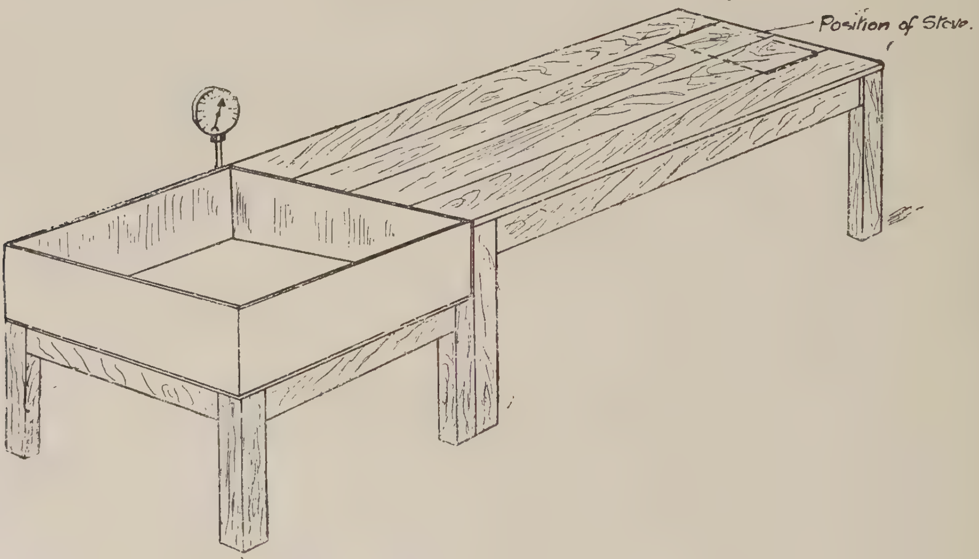

Position of Stove.

Fig. 522.—Repair Bench and Water Tank.

Method of Testing

Generally, testing is the preliminary and concluding performance in radiator repair work. For testing, makers of service equipment supply rubber plugs suitable to close the inlet, outlet, and filler-cap apertures. Discs of sheet metal also are often used. The latter should be cut to suitable size and soldered on the inlet and outlet connections and sealing up any other parts. A hole should be made in one of the sheet-metal discs, and a tapered tube soldered around the hole. Rubber hose is then placed over the tube and air is then let into the radiator under a few pounds' pressure (3 to 15 lb. is sufficient), and the radiator completely submerged in a tank of clean water, when the position of the slightest leak will be located by tell-tale streams or bubbles arising to the surface of the water. If several leaks are noted, as is often the case, little sheet-metal clips may be fastened to the tubes or core at each point of leakage, so that repairs may there be effected before replacing the radiator in the water tank for further tests.

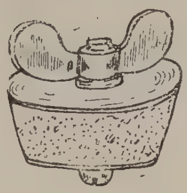


Fig. 523.—Rubber Testing Plug.

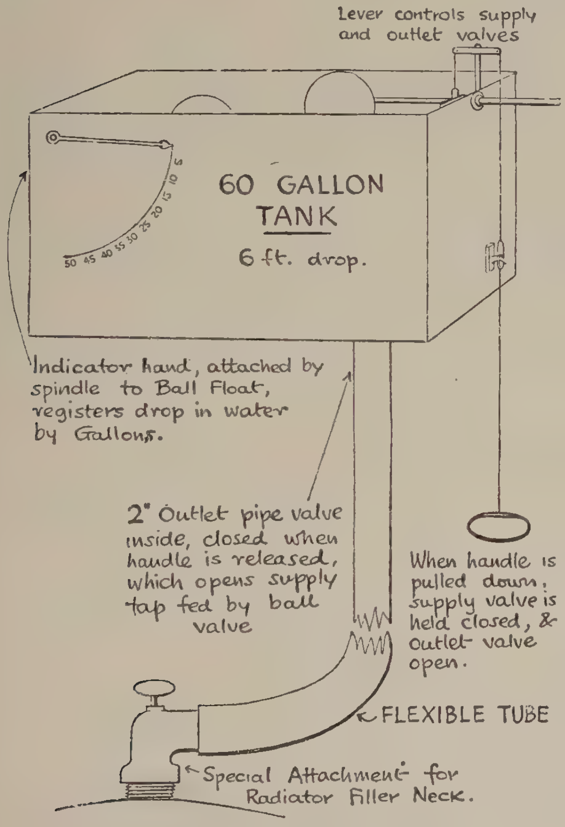

Lever controls supply and outlet valves
60 GALLON TANK
6 ft. drop.
5
10
15
20
25
30
35
40
45
50
Indicator hand, attached by spindle to Ball Float, registers drop in water by Gallons.
2" Outlet pipe valve inside, closed when handle is released, which opens supply tap fed by ball valve
When handle is pulled down, supply valve is held closed, & outlet valve open.
FLEXIBLE TUBE
Special Attachment for Radiator Filler Neck.

Fig. 524.—Radiator-testing Plant.

Some radiator-repairing firms do not consider cold water and air-pressure tests sufficiently adequate, and they have installed special vibration equipment. The repaired radiators are mounted on benches which are oscillated vertically to represent excessive road vibration. Boiling-water tests also are employed.

In some garages and automobile repair shops it is the practice to merely fill the radiator after inlet and outlet connections have been sealed or plugged, and watch for possible leaks. Obviously, this is not a satisfactory test. Experience shows that a poorly constructed or repaired radiator will often hold water, but will develop leaks when subjected to slight pressure.

A useful plant for subjecting radiators to a flow test is shown in Fig. 524. A 60-gallon tank is provided with a ball float, the spindle of which has a hand attached to it, outside the tank; a suitable scale is marked on the tank. As the water-level drops, so does the ball, and the hand on the outside then registers the quantity of water released. The hand's travel can readily be checked by means of a stop watch or the minute hand of an ordinary watch.

The release valve is opened by pulling the chain; it can be fixed in the open position. One lever only is necessary to open the release valve, automatically closing the ball-cock or, alternatively, when closing the release valve to open the ball-cock in order to replenish the tank.

A 2-in. outlet pipe is provided, to which are attached pipes of different sizes to connect it to the radiator by means of rubber hose pipe. Lengths of the latter are also used to connect the branch pipes, and in each is a plug which prevents the water running away when not in use.

The plant in question was devised by the Brighton Sheet Metal Works, Ltd., and it can be used to test radiators whilst they are in position on cars or commercial vehicles, provided that the tank is in such a position that the vehicle can be run underneath it.

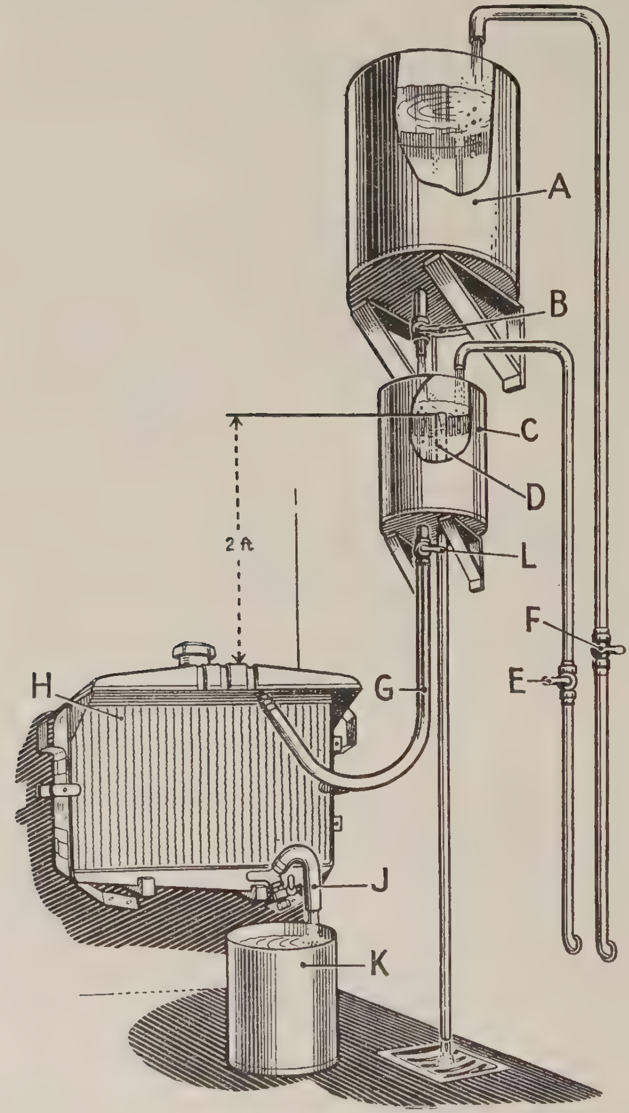


Fig. 525.—Plant or Flow Tests on Radiators (Vauxhall).

Vauxhall Radiator-testing Plant

A simple and convenient flow-test equipment for radiators, used by the manufacturers of the Vauxhall cars and vehicles, is shown in Fig. 525.

The radiator and engine-cooling system in the Vauxhall Velox and

Wyvern cars have capacities of 16½ and 10 Imperial pints, respectively.

The flow-test apparatus, as illustrated in Fig. 525, can be constructed and erected easily, utilising three oil drums for the various tanks (A, C, and K).

Fix two brackets to the wall upon which a radiator assembly H can be rested. Two further brackets at either side fitted with swivel arms may be utilised for holding the radiator in position.

A small reservoir tank C made by cutting about 6 in. off the top of a 5-gallon oil drum is fitted to brackets on the wall above the radiator. From the bottom of this tank a 1½-in. internal diameter stop-cock L controls the flow of water which is led by means of a rubber hose G of the same internal diameter to the top water fitting of the radiator.

Some form of overflow must be provided for this reservoir tank and can be constructed by utilising an old exhaust pipe soldered into the tank so that the distance from the top of the overflow pipe D to the top of the radiator tank is exactly 2 ft.

This dimension is of the utmost importance as it represents the height of the head of water above the radiator when flow testing, and the flow-test figures given later on will only be applicable if this condition is maintained.

Fit the overflow pipe so that its inlet is 2 or 3 in. below the rim of the reservoir tank, thus preventing splashing over when filling with water, as the tank has to be maintained with the water-level up to the top of the overflow pipe throughout the whole of the flow-test procedure. This is necessary to ensure a constant head of water.

Depending on the variation in main-water supply in different districts, it is possible that difficulty may be experienced in maintaining a water-level up to this point, and to overcome this a further 10-gallon oil drum A may be mounted above the reservoir tank to augment the supply.

For districts where water is supplied under high pressure or where a large service pipe is available, the second reservoir tank A should not be required. If, however, it is necessary to utilise the second tank it should be provided with a 2-in. or 2½-in. stop-cock fitted to the bottom so that the water contained in the tank can be turned on to fall directly into the small reservoir tank C. For measuring the quantity of water passing through the radiator under test, a third oil drum K of 5-gallon capacity can be utilised and a short length of rubber hose J will be necessary for directing the escaping water into the tank.

Water-flow Tests

Having ensured that the radiator is water-tight, it should be flow-tested to ensure that there is no obstruction in the water passage which will interfere with the circulation, thus upsetting the cooling properties.

To carry out the flow test, the radiator H, Fig. 525, is clamped in position on the brackets and the flexible rubber feed pipe G from the reservoir tank connected to the water-inlet fitting as shown in the illustration. The water-supply control tap is then turned on to fill the reservoir tank, which must be maintained in an overflowing condition to keep a constant head of water during the test.

If it is found that there is insufficient flow of water from the pipe E into the reservoir tank, the stop-cock B should be turned on, allowing water to flow from the auxiliary tank A to augment the supply.

Fix a short piece of rubber hose J to the bottom radiator outlet and turn on the tap of the flexible feed pipe G from the reservoir so that water commences to flow through the radiator.

To ensure that water is passing through all the passages in the cooling element and that the top tank is properly filled, temporarily seal the radiator outlet pipe with the hand until a steady flow of water emerges from the overflow pipe, then release the outlet pipe. With a stop watch in the right hand, place an empty 5-gallon drum K under the radiator outlet with the left hand, starting the stop watch as water from the radiator commences to enter the drum. The time required to fill the drum should be recorded.

When using a 2-ft. head of water for testing, as measured from the top of the overflow pipe to the top of the radiator tank, the time taken to fill a 5-gallon tank (K, Fig. 525) should be 21 *seconds for the Vauxhall Velox radiator* and 27 *seconds for the Wyvern one.*

The capacity of the cooling system in the Vauxhall Bedford models OWS, OWL, and Bedford Scammell vehicles is 3 gallons 5 pints.

In the flow tests of the radiators of these vehicles the times should be 5 gallons in 17 seconds with a head of 2 ft. of water.

For the OWB model, 5 gallons in 20 seconds with a 2 ft. head.

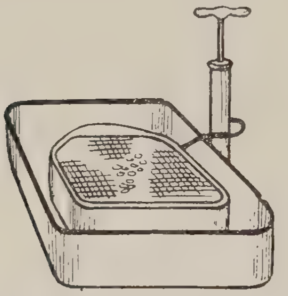


Fig. 526.—Method of testing Radiator for Leaks.

Testing the Radiator for Leaks

A convenient method of testing the radiator is to plug up the inlet, outlet, and filler-cap orifices and connect a tyre pump to the overflow pipe. If the radiator is then immersed in a bath of water and pressure be applied by means of the pump, bubbles of air will issue from the leaking tubes (Fig. 526).

Radiator Repair Method

Unfortunately, many radiators are sent to tinsmith's or sheet-metal repair shops to be put right when damaged or badly leaking and occasionally these general repair shops are without proper knowledge, methods, or equipment. In consequence, the radiator often develops leaks immediately it is reassembled on the chassis, actually at the so-called repaired areas.

The mechanic or repairman who attempts radiator repairing without any previous instruction will have plenty of trouble before getting radiators water-tight, but having once thoroughly mastered the art, little, if any, difficulty will be experienced. A little time spent in thought before commencing to effect the repair is good advice, and may save the mechanic or repairman from making leaks instead of repairing them, as intended.

Radiator repairing is fundamentally and actually in the majority of cases simply a function of good soldering, and to ensure this, correct methods with good materials must be used. The writer gets the best results by using " B.S. soft solder, grade B "—the solder being a uniform alloy of tin, antimony, and lead; its analysis is 49 (min.) to 51 (max.) per cent. tin, 2·5 (min.) to 3 (max.) per cent. antimony, the remainder lead. This solder flows freely, and presents a bright surface when the seams or joints are finished. It can be used in automobile repair work for every purpose to which soft solder is applicable.

Radiator Repair Procedure

The procedure advocated in the case of radiator repairs of a more serious nature can best be illustrated by taking as an example the recommended practice for the Vauxhall cars.

If the radiator cooling element or tanks have sustained serious damage as the result of an accident, the cheapest and most satisfactory method is to fit new components, i.e. a new cooling element or new tanks.

To remove the top and bottom tanks the radiator must be dismantled from the shell and supporting strap. Apply a blow-pipe flame along the seams where the tanks are joined to the cooling element and also to the clips securing the overflow pipe in position. *Remember to keep a generous supply of flux at these joints* to assist the solder to flow.

Cleanliness, when fitting old tanks to new cooling elements, is a very important factor, as a good joint can only be assured if the faces to be sealed are thoroughly cleaned and well tinned. After the tanks have been removed, if they are to be fitted to a new cooling element, they should be cleaned with " unkilled " spirit and then retinned along the face of the joint by using a suitable flux and solder applied with a blow-pipe flame for preference to ensure an even coating.

The radiator-cooling element, as received from stock, is already cleaned and tinned; it therefore requires only to be wiped along the edges to be joined to the tanks with a little flux.

Place the radiator bottom tank upon the assembly stand with the open side upwards and stand the cooling element in position upon it, so that the front edge of the cooling element is level with the edge of the tank flange, tacking the tank to the cooling element with solder in one or two places by means of a gas iron or large soldering iron.

When the bottom tank has been positioned and tacked, the top tank should be placed on the assembly stand with the open side upwards, and the radiator-cooling element reversed and placed upon the top tank, which is tacked to it at several points, taking care that the edge of the tank flange is level with the front of the cooling element.

A chisel-shaped gas iron is then applied to complete the sealing operation, being gradually drawn along the joints, after applying flux, thus running the solder between the tinned surfaces to effect a seal. It is essential that the iron be thoroughly hot during this work and that it is not allowed to remain in one position longer than necessary to make the solder flow properly. A little practice will, however, soon enable the operator to determine when the solder is sufficiently fluid.

The radiator should always be held in a nearly upright position when soldering tank joints to prevent the solder spreading along the ends of the cooling element and thus restricting the water passages.

After the top and bottom tanks have been fixed, the overflow pipe must be secured in position and the radiator submitted to a pressure test under water, as already described, sealing any slight leaks which may be apparent.

Minor Radiator Repairs

Dismantle the radiator-cooling element and tank assembly from the shell by removing the small set-screws. Seal the inlet and outlet pipes with suitable bungs and screw on the radiator filler cap.

Connect the air-feed pipe to the overflow pipe (Fig. 526) *and submerge the radiator entirely* in a test tank of water. Gradually increase the air pressure in the radiator until a maximum of 5 lb. per sq. in. is reached. Watch carefully for air bubbles which may escape, and trace the source from which they appear.

Having noted the latter, lift the radiator from the tank and place it upon the rack at the side, cleaning the affected portion with " unkilled " spirit. Afterwards, apply a suitable flux and seal the leak with a blow-pipe flame reduced to the smallest possible jet to localise the heat. Repeat the pressure test to check if the repair is sound. Should the leak occur at the edge of the cooling element or in the tanks where they are covered by the supporting straps, it will be necessary to remove the latter. These straps are clenched at the joints and *should be annealed* before an attempt is made to open the joint, as this will lessen the risk of a fracture.

Soldering Fluxes

A great deal could be written on the relative advantages of soldering fluxes (fluids and pastes) for soldering metals and alloys in radiator and other automobile repairing; but, broadly, soldering fluxes are divided into two classes: (1) corrosive and (2) non-corrosive. Examples of class (1) are zinc chloride, hydrochloric acid, ammonium chloride, etc.; examples of class (2) are resin, tallow, olive oil, stearine, etc. Mention should also be made of the more convenient solder pastes and creams which contain both flux and solder and are merely applied by painting on with a brush. Upon heating the surface it becomes efficiently "tinned."

The rapidity with which a soldering flux acts is an important factor in its usefulness. If the flux be in the form of a dry salt, a comparatively high heat is necessary to fuse it. If an aqueous solution be used, a certain amount of heat is essential to evaporate the water. The function of a soldering flux is to have a solvent action on the oxide, thereby keeping the metal surface clean and excluding the air.

Resin is a good non-corrosive soldering flux where speed is not required. But it has the undesirable property of leaving a sticky gummy mass on the metal surface. It is, however, a splendid flux for soldering cables into lugs or other automobile electrical fittings, and it is a fair insulator. Ammonium chloride is often used as a soldering flux on brass and copper automobile parts, as it does not tarnish these metals. Zinc chloride has several properties which make it a valuable soldering flux for radiator repair and most automobile sheet metals, as it remains liquid at the temperature of molten solder, thus being in a condition to act upon the oxides very readily. It has a corrosive action on radiator metal, however, so that after using it the parts soldered should be cleaned thoroughly.

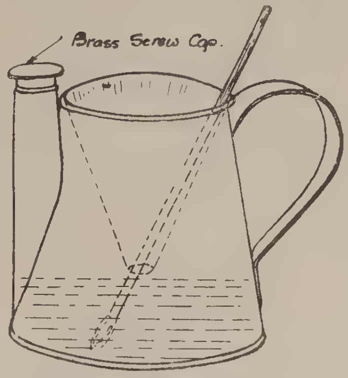


Fig. 527.—A Useful Receptacle for Soldering Flux.

Some motor mechanics add a quantity of water to zinc chloride flux, but that is detrimental, because the stronger the flux can be made and still remain liquid the better it will be. To make zinc chloride flux, dissolve sufficient clean metallic zinc (preferably in small pieces) in hydrochloric acid until the violent ebullition caused by its introduction has ceased. Be sure to provide an excess of zinc, observing that a quantity remains undissolved after all chemical action ceases. The zinc should remain in the acid for about twelve hours; then pour off the clear liquid into a receptacle for use. In Fig. 527 is shown a useful sheet-metal non-spillable receptacle for soldering flux (zinc chloride), designed for use in the automobile repair shop. The principle of the construction of this is the same as that which is embodied in the non-spillable inkwell. The receptacle is fabricated from sheet copper $\frac{1}{32}$-in. thick, and all the joints are securely soldered. Both handle edges are folded, rolled, and the piece soldered to the receptacle as shown.

In radiator repairing, an atmospheric-gas blow-pipe and air-acetylene torch are among the most useful tools; in many cases obviating the necessity for special tools, as the torch needle flame can reach places where the use of the soldering bit is out of the question owing to its size, though, of course, in some instances flame torches are not suitable. For example, when there are leaks in two different walls of one cell of a honeycomb radiator, if the leak of one wall was soldered the flame would remelt this solder when attempting to solder the other wall. Furthermore, great care is necessary in the manipulation of the torch flame, as the brass or copper of which cell walls are usually made is very thin (being made of sheet metal about ·005 to ·002 in. thick), and a hole can be burnt in the thin metal very easily.

For such cases, a special soldering bit should be used. A suitable one can be made from ¼-in. or ⅜-in. square copper bar. It should be made rectangular in section, and pointed at the end (see Fig. 521 (2)) for working to and fro in the cells. The length of the bit should be from 4½ to 5 in. Fig. 521 (1) shows an ordinary pointed soldering bit used for general work. In Fig. 521 (3) is shown a bent or curved soldering bit which enables many parts or points of the radiator to be reached which are inaccessible with an ordinary bit. Fig. 521 (4) shows a useful tool (designed by the writer) for soldering around the tube ends on the tube header plates. The bit has a hole bored in its end, slightly larger in diameter than the exterior of the tube of a tubular type of radiator. The metal at the end around the hole is ⅛-in. thick.

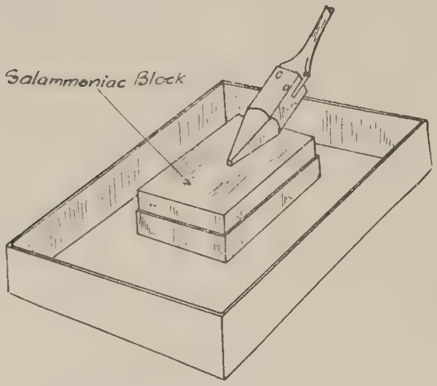


Fig. 528.—A Useful Tinning Block.

Before a soldering bit can be used effectively it must be tinned. That is, the point or tip must be coated with a tin-lead alloy—solder. When tinning soldering bits, first remove the coating of oxide which always covers a soldering copper, by filing the bit faces shapely and bright after it has been heated a dull red colour in a clean fire. To tin the soldering bit after the cleaning process (filing), hold it down firmly in the cavity of the sal-ammoniac block, see Fig. 528, and melt a few globules of solder into the cavity along with the bit, and the latter will become brightly tinned in a second. The soldering bit should be applied to the sal-ammoniac block every few heats, or as required, as the work progresses.

The method of dipping the soldering bit into zinc chloride or ammonium chloride solution for cleaning the copper (sometimes practised by automobile mechanics and repairmen) is both slovenly and wasteful, for not only is this corrosive-acid solution sprayed about broadcast in the garage or repair shop, rusting and tarnishing all the steel and non-ferrous metal parts within range, but the bit faces soon become " honeycombed," and are soon rendered unfit—as is the zinc chloride—for fluxing.

A good method of indicating whether any soldering bit has the right temperature for soldering operations is to touch the tip with a stick of solder. If it melts instantly the tool is sufficiently heated. When heating soldering bits, either for tinning or soldering operations, care should be taken not to allow the bits to reach too high a temperature, otherwise their life is shortened.

The Importance of Cleanliness

Scrupulous cleanliness in everything connected with the process of soldering is essential to success. All radiator parts to be soldered must, therefore, be made perfectly clean and free from dirt, scale, and metallic oxides. This cleanliness should be both mechanical and chemical. Mechanically clean the surfaces by filing or scraping, and before the air has time to oxidise the clean surfaces, chemically clean them by applying the soldering flux.

Old radiator fittings are sometimes difficult to solder properly, due to the fact that they are covered with hard scale, rust, etc. A good method to clean these fittings is to heat them a dull red colour and immerse them in hydrochloric-acid solution (7 parts hydrochloric acid and 3 parts water), when they may be readily soldered.

Tubular-type Repairs

The best procedure when a tube in a tubular type of radiator leaks its entire length, or is badly damaged, is to install a new tube. As previously indicated, the tubular type of radiator on the heavier types of chassis is generally fitted with separate cast top and bottom tanks bolted to the tube block. The detachable top and bottom tanks offer great advantages from the "repairability" view-point, and, in addition, enable cleaning to be carried out easily when water supplies are indifferent.

When new tubes are required, first remove the top and bottom tanks Sometimes it is necessary to strip off a few fins from the tube, so as to allow one end to be pushed through the tube plate. Both tube ends should be well tinned, also the tube-plate areas near the tubes, before inserting the tube ends in the plate. The latter should be countersunk around the tube ends, or the tube ends should protrude sufficiently above the plate to allow a good body of solder to be put round them. With some tubes slightly drifting the ends strengthens the repair. After the tubes have been soldered in position, thoroughly wash the soldered areas with clean water, and then refix the top and bottom tanks. Graphite jointing paste, or "Smooth-On," mixed with water to form a cement, may be used in addition to a rubber washer to make the joint water-tight. The "Smooth-On" cement preparation may be used for temporary repairs without removing the radiator from the chassis. Fig. 529 shows this cement being firmly packed around defective tubes on a Ford radiator.

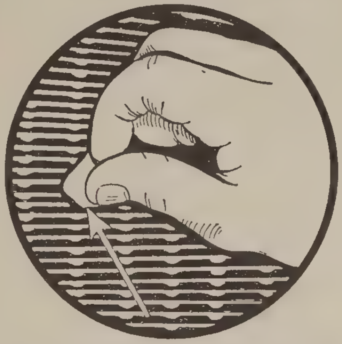


Fig. 529.—Method of stopping Leaks for Temporary Repairs.

Honeycomb-radiator Repairs

When a honeycomb-radiator core or cooling section is badly damaged so as to be beyond satisfactory repair, it generally proves to be economical to remove it and put in a new core, see Fig. 530. Honeycomb cores are best removed by the use of a torch or blow-pipe flame, as contrasted with the method of removing tubular cores by chiselling cores or tubes from the water tanks. Play the flame on the core where it is soldered to the tank, melting the core away inch by inch. When a new core or cooling section has been rebuilt, the radiator should be as good as a new one, and at much less cost than purchasing a new radiator.

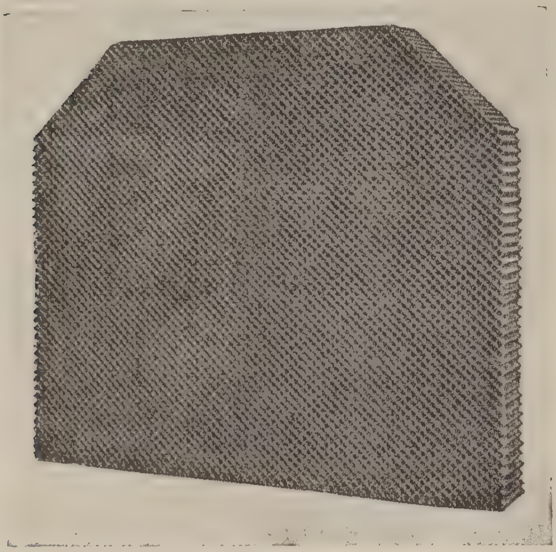


Fig. 530.—New Radiator Core.

To solder a leak in the cell of a honeycomb type, first locate the leak, then with a suitable scraper clean the surface around the defect thoroughly. In honeycomb-radiator repairing, there are so many different-shaped places to be got at that a variety of different shapes and sizes of scrapers come in useful. Fig. 531 shows a cell scraper made from steel wire. The end is hammered over in the vice about $\frac{1}{8}$ in. and filed sharp as shown. In some cases radiator cores may be cleaned with hydrochloric acid applied with a piece of soft cloth attached to a wire. When the metal is thoroughly cleaned, apply a fine needle flame of an air-acetylene torch or coal-gas blow-pipe; the repairer must be very careful not to burn the radiator-core metal. When heated to a temperature of about 300° F., squirt on a little soldering fluid. This will temperarily cool the area to be soldered; continue to hold the flame on the defective area until it reaches the melting-point of solder, then apply the solder in wire form, and if the cleaning has been thorough, the solder will readily flow over and adhere to the metal surface.

When the damage is spread over the area of several cells, a temporary repair can be made by a patch of thin sheet brass or copper, soldered to front and back faces, covering completely the damaged area. After the soldering process, it is always necessary to wash the repaired areas with hot water to prevent subsequent corrosion of the metal.

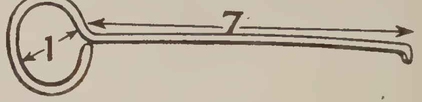


Fig. 531.—A Radiator Cell Scraper.

A most useful honeycomb-radiator repair accessory consists of a couple of small plates or washers with a piece of rubber sheeting fixed on; these plates have hooks so that a spiral spring can be fixed on to draw them together. The spring is threaded through the aperture at the leaky cell, the plates hooked on, and thus held firmly up against it.

Not infrequently it is stated that the honeycomb radiator is very expensive to repair; actually it is the least costly of any, since it is the only type in which damaged or defective areas may be repaired or replaced without dismantling the radiator parts, e.g. the removal of a leaky radiator to permit of soldering can often be obviated by the following procedure, provided the leaks are not too numerous. The areas to be soldered will afford no difficulty to being well tinned, but solder in quantity sufficient to close a leak frequently drops or flows away. After tinning the parts to be soldered with the hot bit, allow the soldering bit to cool down until it will just melt the solder, and then the molten solder may be wiped over the leak without dropping off.

Removing Dents from Radiators and Casings

The art of smoothing, straightening out, and removing dents from sheet-metal radiator tanks and casings often presents difficulties to the automobile repairman that are merely apparent, and may easily be overcome by a little practice, and study, in one or other of the following:

(1) To remove dents from badly dented radiator tanks and casings, solder a piece of stout wire in the centre of the dent. After the solder has set, the wire can be given a strong pull so that the metal will be pulled outward. The wire can afterwards be removed by heating the end until the solder melts. A wire bent to form a handle, as shown in Fig. 532 at A, will be found to be a useful tool for this work, and it can be kept on hand in the repair shop for the next job. Sometimes when the dent is not eliminated satisfactorily by this method, a few light blows with a flat-faced bright hammer delivered around the edges of the indentation will greatly improve the appearance. If a polished radiator has been dealt with, very fine emery cloth and oil should be first used to remove every trace of solder, afterwards rotten stone and oil, or tripoli and oil, should be used, finishing off with dry powdered lime. Buffing is essential for highly polished radiator parts.

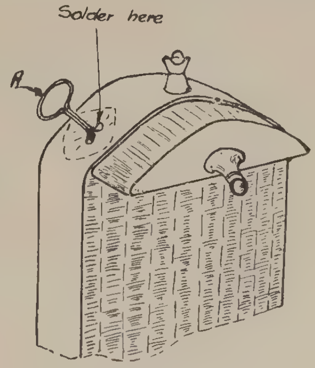


Fig. 532.—Removing Dents.

(2) A novel and easy way to remove unsightly dents from sheet-metal radiators of the Ford type is to fill the radiator completely with water, and plug up all openings (employing suitable corks, wooden or rubber plugs), except the brass tap at the bottom. To the latter apply an ordinary pneumatic tyre pump with connections of the push-on type with rubber tubing, and put sufficient air pressure inside the radiator to force or bulge the dent outward. Then lightly hammer a piece of smooth, hard wood around the raised edges of the dent. By this method the radiator will attain its original shape, eliminating both small and

large dents. Care must be taken, however, that the air pressure applied is not so great as to bulge the thin metal in some other part of the radiator.

(3) The radiator casing should rest upon a convex-shaped iron stake during the process of smoothing, after the dents have been partly removed by bumping them on the underside. The fact should be emphasised that the repairman cannot be too careful to bring the hammer down flat upon the radiator-casing surface every time, otherwise crescents will appear, as previously indicated, and it will be found exceedingly difficult to obtain a perfectly smooth surface, which is so essential on high-class automobiles.

(4) Not infrequently small indentations can be removed from radiator casings by laying the latter on a piece of hard wood convex-shaped and rubbing thoroughly the outside surface with a piece of smooth wood. This method will often bring the small defects up level to conform with the contour of the casing without hammering or severely marking the metal surface.

General Notes on Radiators

Many radiator troubles can be avoided if the radiator is kept clean internally and rust from the water jacket is not allowed to accumulate in the radiator.

The best way to keep a radiator in first-class condition is to make a practice of flushing it out every 5,000 miles of running of the car. This is usually done by leading a hosepipe to the radiator-filler orifice. If this is done regularly, the cooling efficiency of the radiator is maintained, and the possibility of the tubes being obstructed is almost entirely eliminated.

If a radiator is damaged or begins to leak, it can be repaired at a small cost, provided the work is put in hand without delay. If, however, the repair is postponed, it will almost certainly cost more in the end. For example, if a radiator begins to leak where the film portion is joined to the tanks and casing, a satisfactory repair can often be made without removing the film block; but if the repair is put off, the leakage will extend rapidly, and the radiator will have to be taken completely apart to repair it.

In the same way, a small perforation in the block itself can be repaired if it is attended to at once by a capable firm of repairers. But if matters are allowed to slide, the leaking tube will probably split, leading to further complications, and in the end a complete new block may be necessary.

The various " stop-leak " preparations on the market are undoubtedly of considerable value on the road, but it must be pointed out that there are limitations to the utility of these preparations, and that the defects in the radiator which cause the leaks should be attended to as quickly as possible.

Cases have been brought to our notice where the tubular sections of the radiator have been filled up by repeated application of radiator cement, and the circulation of water almost completely stopped.

The Fan Drive

The fan for assisting the radiator to cool the water flowing through its water spaces is usually driven from the engine crankshaft pulley, the V-belt of which also driving the dynamo. The fan is driven at a rather higher speed than that of the crankshaft, by about 20–30 per cent. It is necessary to keep the fan belt tensioned sufficiently to prevent any slipping under load, but excessive tension should not be used, otherwise the dynamo and fan-shaft bearings will tend to wear at a greater rate and more power will be required from the engine to drive the dynamo and fan unit. Provision is always made in modern engines for taking up any undue slack in the V-belt. Usually, this is effected by mounting the dynamo on hinged plates, one of which is slotted for the adjustment. Three bolts and nuts are then fitted, namely, one for each plate hinge and the other for locking the radiator side plate once the belt is adjusted; the two plate-hinge bolts are also locked securely by their nuts.

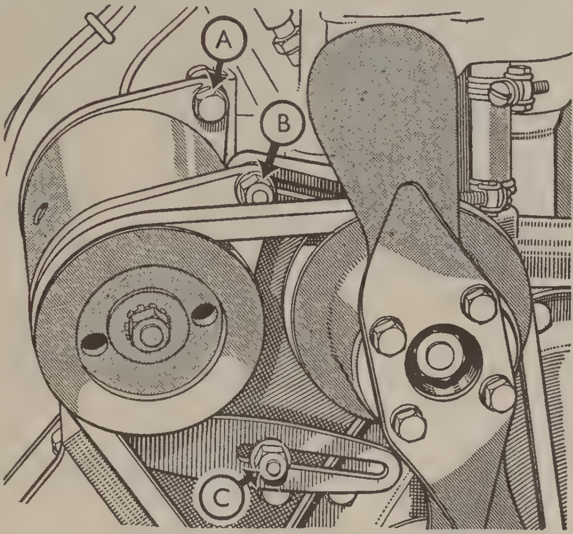


Fig. 533.—Typical Method of Tensioning Belt.

Fig. 533 illustrates the method of adjusting the Austin A40 fan and dynamo driving V-belt. The dynamo is mounted on plates at each end which are hinged to engine brackets at A and B by the bolts A and B. On the radiator end plate of the dynamo there is a slotted extension portion which is locked to the engine by the bolt and nut C. To adjust the belt, all three nuts at A, B and C should be slackened off and the dynamo moved upwards by pulling or lifting with the hand, until the belt is adjudged to be correctly tensioned, when the three nuts should be tightened securely. Usually, the correctly tensioned fan belt should

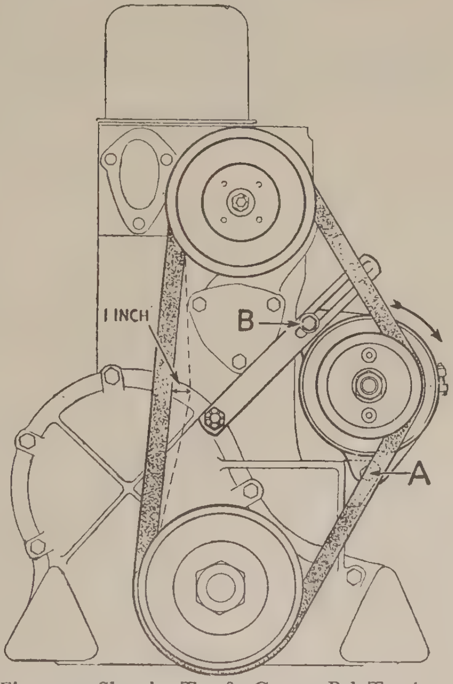


Fig. 534.—Showing Test for Correct Belt Tension, by Lateral Movement of Belt (Morris Commercial Engine).

have about 1 in. lateral play between the V-pulleys at the longest side as tested by moving the belt sideways in the plane of the three pulleys (Fig. 534). A worn belt will " bottom " on the V-pulleys, and will therefore slip without driving the dynamo or fan at their correct speeds. If this cause is suspected, remove the belt and examine the bottoms of the pulleys for wear effects—as indicated by polished bottom surfaces.

The Thermostat

The thermostat is fitted for two main purposes, namely, (1) to enable the cooling water in the cylinder block to warm up as quickly as possible from the cold, and (2) to maintain the cooling water at its correct working temperature, so that the engine will operate under the most efficient thermal conditions.

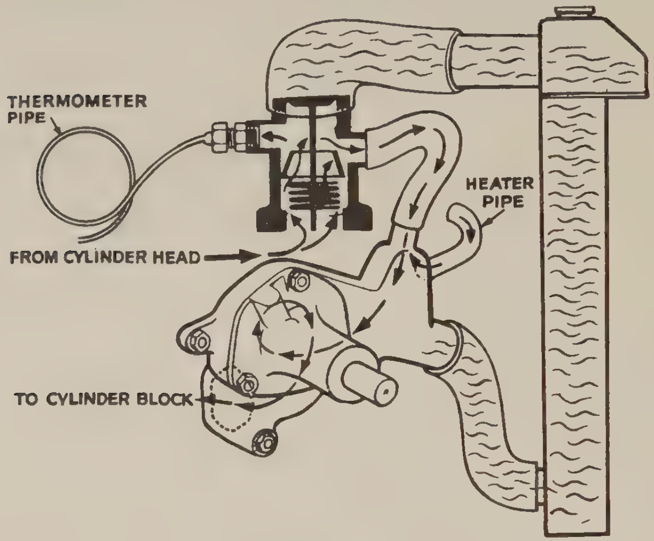


Fig. 535.—Illustrating Action of the Vanguard Thermostat (Cold Condition).

The principle of the cooling-system thermostat is that of an element, known as a thermostatic one, which, when the water is cool, closes a valve that shuts off the radiator from the cylinder water jackets. When the engine warms up it heats the jacket water to a certain temperature, and this also heats the thermostat, causing it to expand and thereby open the valve. This allows the heated water from the jackets to flow to the top of the radiator, down through the water-cooling spaces of the latter, and from the lower radiator tank to the bottom of the cylinder jacket (or jackets).

The action of the thermostat is well illustrated in the case of the Vanguard cooling system, shown in Figs. 535 and 536. The thermostat, as in other examples, consists of a kind of closed multiple bellows filled with a light spirit vapour such that when the element is heated the vapour-pressure effect causes the bellows to lengthen, thus closing the lower (by-pass) valve and opening the upper thermostat valve.

Referring to Fig. 535, this shows the conditions when the engine is cold. The contracted bellows element has opened the by-pass valve and closed the upper valve. The net result of this is to shut off the cylinder-head water flow from the top of the radiator and allow the water pump to circulate water up past the by-pass valve, the cylinder jackets, and down the by-pass pipe shown by the arrows. It will be observed that no water flows through the radiator, but circulates only around the cylinder and head water spaces.

As the engine heats up, the cooling-water temperature is raised until at a given value, namely, about 155°–165° F., the upper valve is lifted by the expansion of the bellows and the by-pass valve closed. The hot water from the cylinder jackets and head spaces is then free to circulate through the radiator system as shown by the arrows in Fig. 536.

In the Vanguard engine cooling system there is a thermometer that is mounted on the instrument panel and connected with the cooling water system by means of a fine-bore metal tube which is shown in Figs. 537 and 538; the connection is made to the water space above the bellows element, between the by-pass and thermostat valves.

Testing the Thermostat

After being in service for long periods, or in the case of engines that have stood for appreciable periods without being used, the thermostat may not operate, or if it does it may not open and

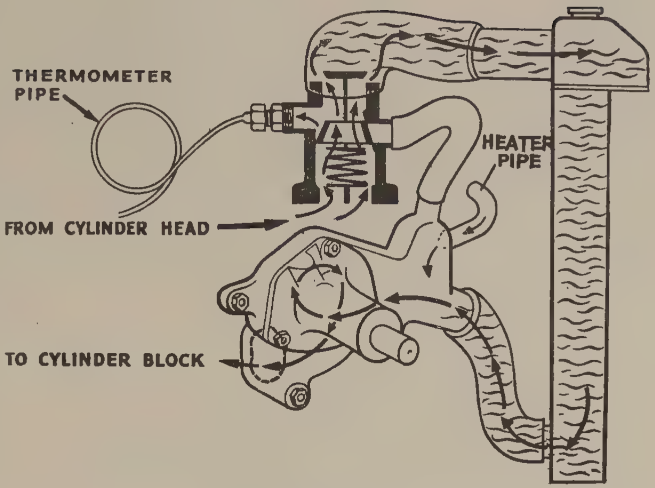


Fig. 536.—The Thermostat shown operating under Warm Conditions.

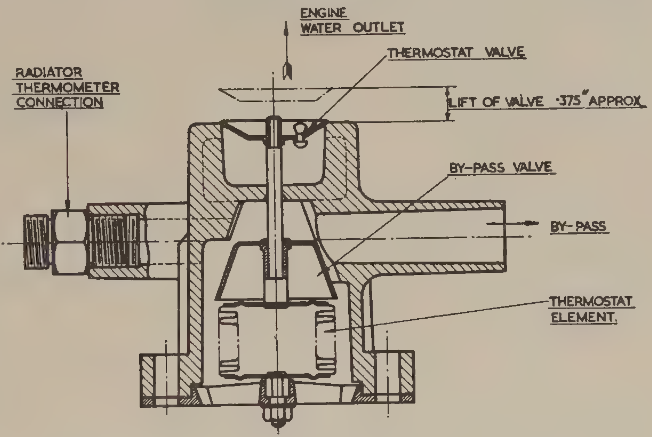


Fig. 537.—The Vanguard Thermostat, showing Thermometer Connection.

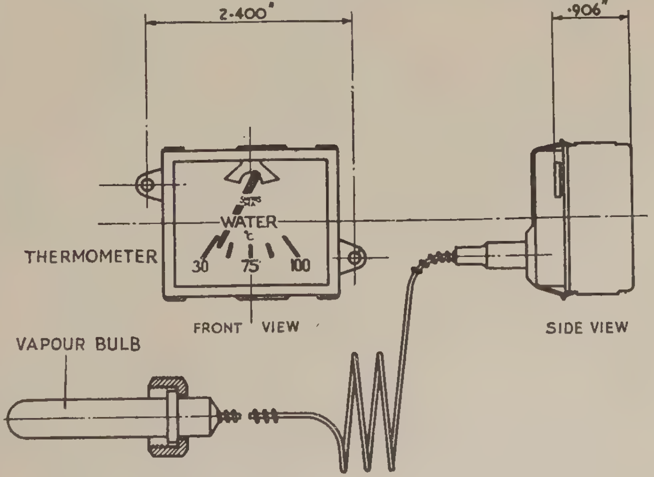


Fig. 538.—The Vanguard Radiator Thermometer Connection.

shut at the correct temperatures. It is always advisable, therefore, to inspect and test the complete thermostat every time the engine is decarbonised or overhauled. Usually, the method of securing the thermostatic unit will be obvious from an inspection of the cooling system; as a rule it means undoing two or three hose clips or removing two or three set-screws.

To test the thermostat, suspend it in a glass vessel containing water with a thermometer graduated to read the boiling-point (212° F.). Heat the water gradually and read the temperature. The thermostat valve should be in a position where it can be inspected, and, as the temperature passes through the 100° F. mark, the valve should be carefully watched, so that the exact temperature of the valve opening can be checked. This temperature should be about 155°–165° F., but as the water is heated still further it will be observed that the valve continues to open until, if it is working correctly, it should be fully open when at a temperature of 180°–190° F. The actual temperatures vary somewhat with the design of engine and cooling system, those given being the average values for the *open* as distinct from the *closed or pressure* cooling system, to which reference is made later.

It is important to *suspend both the thermostat and thermometer in the glass vessel* so that they *cannot touch the bottom of the latter*; otherwise a wrong reading will be obtained, and the thermometer may be damaged.

Should the thermostat fail to operate when tested in the manner described, it should be examined to ascertain whether the cause can be remedied; often corrosion of the stem or valve face and seating will be discovered. If the wear or corrosion is appreciable the thermostat should be replaced by a new one.

It may here be mentioned that apart from the direct-operating valve-type thermostat shown in Fig. 537 there is another pattern in which the bellows element moves the shaft of a butterfly valve in the upper water passage from the cylinder head to the top tank of the radiator.

Pressure Cooling System

Certain modern engine units, notably the Vauxhall Velox (but not the Wyvern) and the Morris Minor, employ the pressure cooling method, whereby the complete system is sealed against the atmosphere, so that when the cooling water heats up there is a positive pressure (above atmospheric) in the system. This raises the boiling-point appreciably and enables a smaller radiator to be used, and provides a protection against high altitude or tropical conditions; moreover, the engine runs more efficiently.

There is a pressure relief valve in the filler cap to prevent the pressure rising too high. In the Velox engine unit this valve opens at 4 lb. per sq. in. above atmospheric pressure, and allows the escape of steam or water through an overflow pipe; the corresponding boiling-point of the water is raised from 212° to 223° F. There is also a second relief valve which prevents a partial vacuum forming in the cooling system when the water cools down; otherwise the radiator would be under atmospheric pressure all the time the system is cool. The vacuum valve allows air to enter as the water cools down. This valve is also in the filler cap. Fig. 539 shows the filler cap used on the Morris Minor radiator This has projecting tongues which engage with the filler-spout inclined surfaces or cam to produce an airtight joint. If it is necessary to remove the cap when the water is hot, *great care must be exercised to prevent the escaping steam from burning the hand*; the cap should be released very gradually, and a thick leather glove worn when undoing the cap. The cap washer must be kept in good order to ensure an airtight joint.

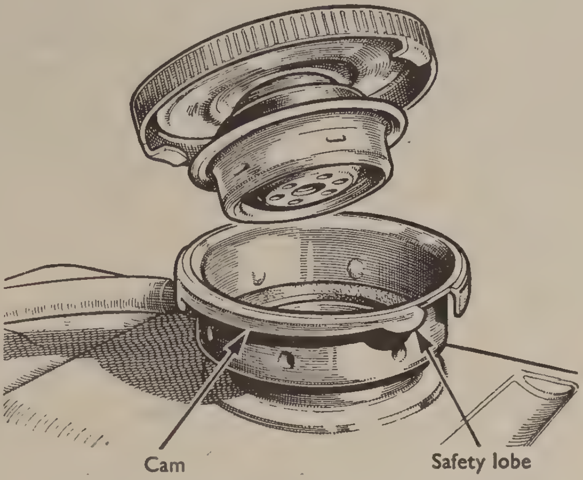


Fig. 539.—The Filler Cap of the Morris Minor Radiator.

The Radiator Thermometer

In some cars a thermometer of the dial pattern is fitted on the instrument panel to indicate the cooling water temperature and thus provide a check on the engine operation (Fig. 538). The usual working temperature of most car engines of the open thermosyphon cooled type lies between about 170° and 190° F., and the thermometer, placed in the cylinder-head cooling or near the upper side of the thermostat, should indicate this temperature. Should the *thermometer show a higher reading* than the normal value—recommended by the car manufacturers, or marked on the dial—this is an indication that there is insufficient water in the cooling system or that the engine is operating under other conditions causing overheating; the causes for this are enumerated at the end of this chapter.

If *the thermometer fails to operate satisfactorily* under normal engine working condition it should be removed from the car and tested in water in a vessel which is heated gradually from normal tap temperature up to boiling-point. The readings of the engine thermometer should be compared with those of a mercury-in-glass standard thermometer.

The Water Pump and Fan

In some designs of engine the water pump is located low down on about the level of the crankshaft, and is driven at half engine speed. The centrifugal type of pump is then employed, and has a packed asbestos or carbon disc type of sealing device to prevent escape of water when the pump shaft is rotating. Usually, the shaft rotates on a pair of ball bearings, and a grease nipple is fitted for lubricating these bearings. In one or two modern car engines a screw-down greaser is still fitted, and it is recommended that this should be given a turn every 1,000 miles of road service.

The more widely adopted method for motor-car engines is to combine the fan-shaft and water-pump impeller shaft as a single unit, driving this shaft by means of a belt from the engine crankshaft V-pulley to a V-pulley on the fan-impeller shaft. Fig. 540 illustrates a typical fan-water-pump assembly, namely, that of the M.G. 1¼-litre engine; the Morris and Wolseley engines employ a similar arrangement that differs only in design details.

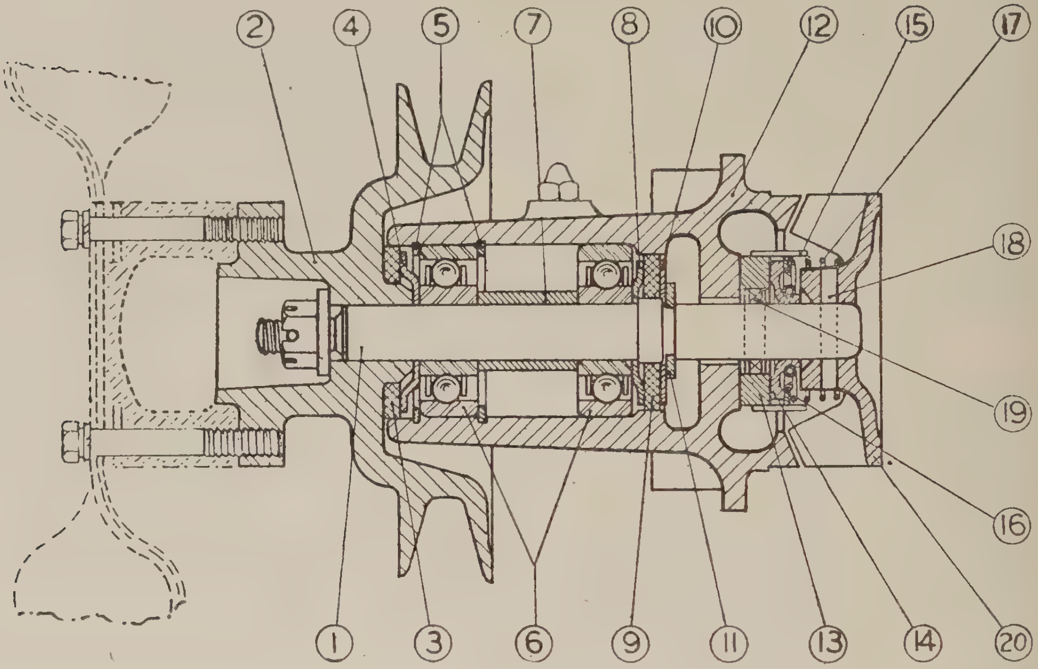


Fig. 540.—The M.G. 1¼-litre Fan and Pump Unit.
1. Spindle. 2. Fan Pulley. 3. Felt Washer (front). 4. Retaining Cover (front). 5. Bearing Circlips. 6. Bearings. 7. Distance Tube. 8. Retaining Cover (rear). 9. Felt Washer (rear). 10. Retaining Washer (rear). 11. Spindle Circlip. 12. Pump Body. 13. Seal Washer. 14. Spindle Seal. 15. Gland Ring. 16. Seal Washer. 17. Seal Ring. 18. Taper Pin. 19. Gland Peg. 20. Impeller Vane.

The fan member is shown dotted on the left. It is four-bladed, and is attached to the pulley boss by four set-screws with lock washers. The pulley is keyed to the common shaft, the latter being mounted in ball bearings having a distance tube between. It will be observed that a grease-gun nipple is provided to lubricate these bearings. Here it may be mentioned that in some designs the bearings are packed with lubricant when the unit is assembled, and since there are effective seals to prevent escape of the lubricant there is *no need to fit a grease nipple or to attend to the lubrication* of the shaft bearings during the life of the engine. The Vauxhall and Bedford pump bearings are of this "sealed" pattern. Reverting to Fig. 540, the felt washers (3) and (9) prevent the bearings lubricant from escaping from the bearing spaces. The impeller of the pump is indicated at (20). It has a sealing unit including a graphite (or carbon) disc that is pressed against the flat face of the pump body (12) around the hole through which the shaft passes. This arrangement, known as the *carbon seal* one, is now widely used for preventing water leakage from the pump shaft, since long experience has shown that the graphite thick disc has excellent wear-resisting qualities and needs replacement only after long periods of service; moreover, it requires no maintenance attention, as with the screwed packed gland method.

Dismantling and Inspecting Fan and Pump Assembly

Access to the bearings is obtained by releasing the impeller and gland. The former is held by a tapered pin to the drive shaft (see (18) in Fig. 540). The pressure spring and washer can then be withdrawn, thus giving access to the carbon seal and gland washer assembly. Care should be taken not to damage the carbon ring, as this is comparatively brittle. The attachment castle nut for the V-pulley should then be removed and the pulley, pulley key, felt sealing ring and retainer (4) withdrawn. A little petrol should be injected into the impeller body around the outer bearing, and the inner end of the spindle then tapped with a piece of wood until the outer bearing can be removed. This will release the distance piece (7), giving access to the inner race.

It should here be noted that before the outer bearing can be removed, it is necessary to remove the outer-bearing circlip (5) with a pair of round-nosed pliers. The inner circlip can be removed after the outer bearing is withdrawn, and the remaining bearing and the impeller spindle taken out.

The bearings and carbon seals should be examined for wear effects; the face of the brass sealing washer for flatness or undue wear, and the felt washers for wear. Any worn or damaged components should be replaced by new ones.

The Morris Six Water-pump Assembly

The various components for this pump are shown in exploded view in Fig. 541; the various parts are described in the caption below the illustration, so that if this type of fan-pump assembly has to be dismantled for servicing, the order of dismantling will be evident from a study of the parts shown.

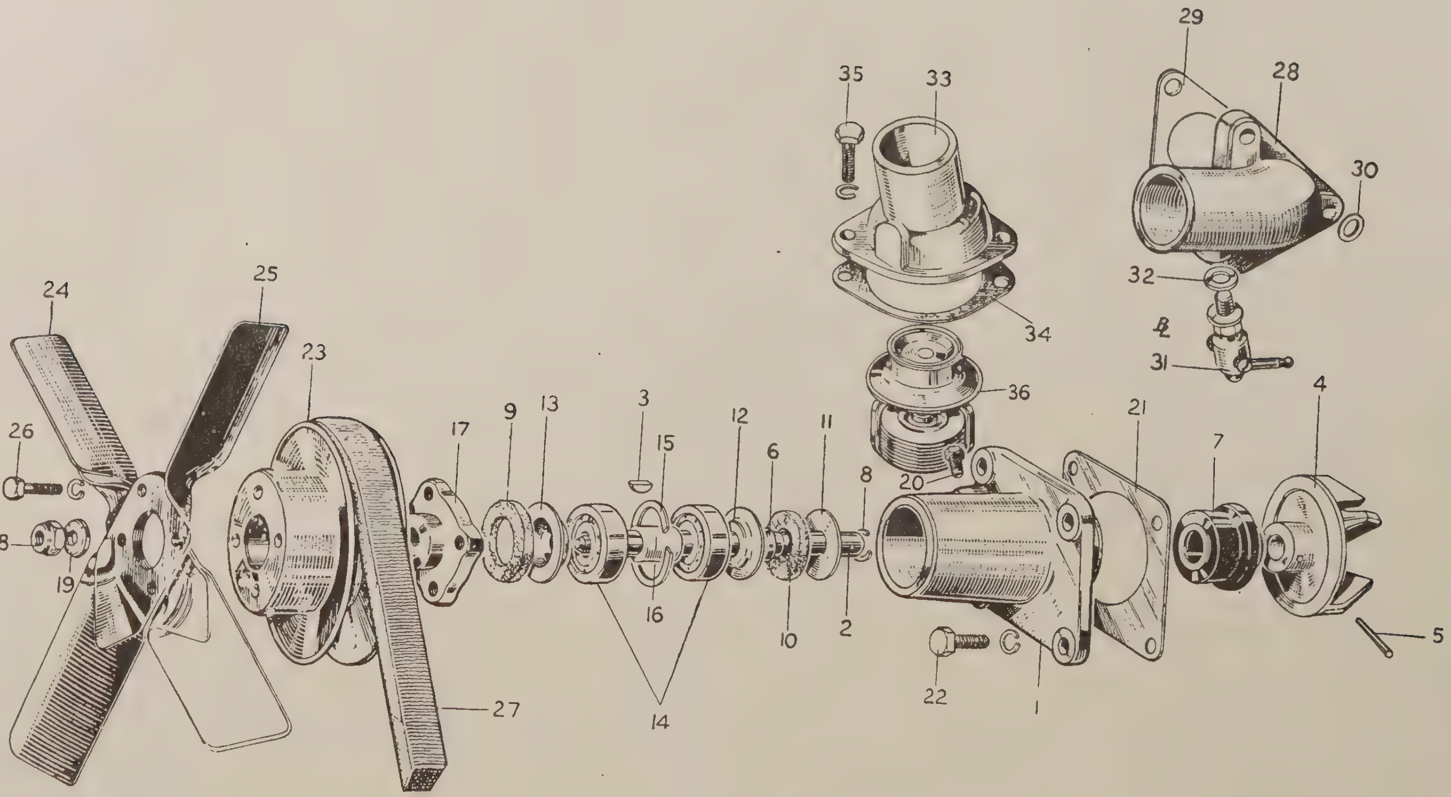


Fig. 541.—The Morris Six Fan and Pump Components.

1. Body—Water Pump. 2. Spindle—Pump. 3. Key—Spindle. 4. Vane—Pump. 5. Taper Pin—Vane. 6. Collar—Spindle. 7. Seal Assembly—Pump. 8. Circlip—Spindle. 9. Felt Washer—large. 10. Felt Washer—small. 11. Dust Cover—small—plain. 12. Dust Cover—small—rear. 13. Dust Cover—large—front. 14. Bearings—Spindle. 15. Circlip—Bearing. 16. Distance Tube—Bearing. 17. Hub—Fan. 18. Nut—Spindle—Self-locking. 19. Washer—Spindle Nut. 20. Greaser. 21. Joint—Pump Body. 22. Bolt—Body to Block. 23. Pulley—Fan. 24. Blade—Fan. 25. Blade (offset)—Fan. 26. Bolt—Blade. 27. Belt—Fan and Dynamo. 28. Water Inlet Elbow. 29. Joint—Inlet Elbow. 30. Washer—Elbow Nut. 31. Tap—Water Drain—in Elbow. 32. Washer—Drain Tap. 33. Water Outlet Pipe. 34. Gasket—Outlet Pipe. 35. Outlet Pipe. 36. Thermostat.

The Austin A40 Water-pump Assembly

The combined fan-shaft and water-pump assembly of the Austin A40 engine is shown in " exploded " view in Fig. 542. Since it is arranged on a similar principle to the one described previously, it is unnecessary to give detailed instructions for its dismantling. In this case a two-bladed fan is employed; it is attached to the V-pulley member by four setscrews with spring washers. Lubrication of the two ball bearings is by oil through a nipple or plug (3) on the fixed bracket (4) containing the bearings and pump body. The sealing-ring assembly consists of a gland spring, metal locating cup, rubber washer, and carbon seal ring with a distance piece (12). The metal locating cap has four driving tags on its smallest diameter which mate up with driving slots on the pump vane. The vane is screwed on to the pump shaft (7) and permanently riveted to same.

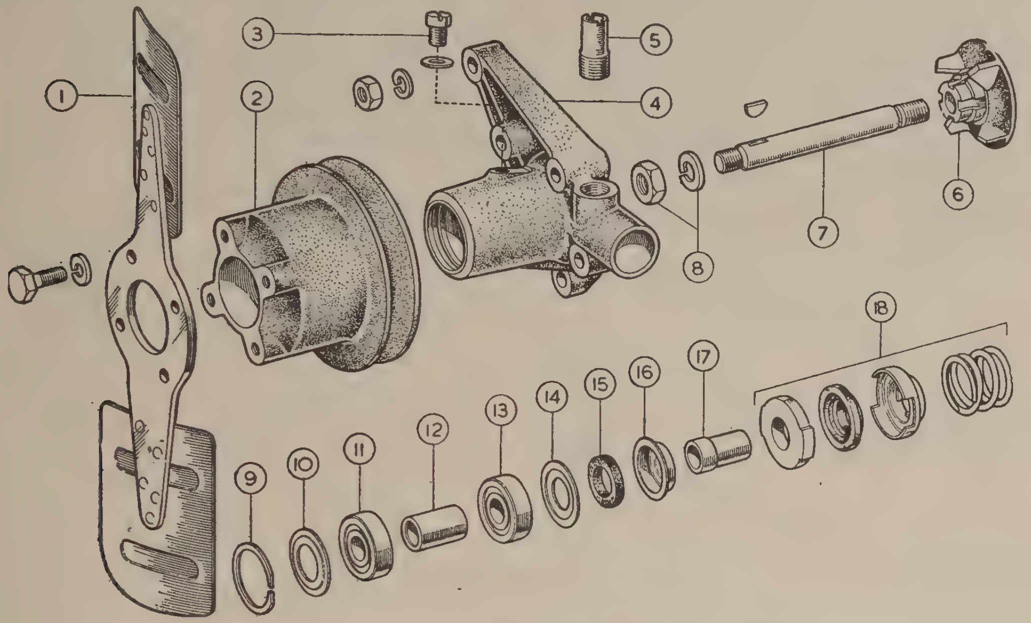


Fig. 542.—The Austin A40 Fan-shaft and Water-pump Assembly.
1. Fan Blades. 2. Belt Pulley. 3. Oil Plug and Washer. 4. Pump Body. 5. By-pass Pipe. 6. Water Impeller. 7. Spindle and Key. 8. Nut and Washer for Spindle. 9, 10, 11. Front Bearing Assembly. 12. Distance Piece. 13, 14, 15, 16. Rear Bearing Assembly. 17. Distance Piece. 18. Gland Assembly.

On the earlier A40s no drive was provided for the carbon seal ring, and this, in some cases, *led to leaking pumps*. In the later models a positive drive, as explained previously, is fitted; the earlier models can, however, be readily modified by using existing parts to give a positive drive.

The Vauxhall Water Pumps

In the Vauxhall Velox engine the water pump is driven by the fan V-pulley in the usual manner, and the thermostat is a separate unit located in the outlet from the cylinder head to the top of radiator. In the case of the Wyvern engine, however, the pump body has an upper extension containing the thermostat. The pump shaft in both models runs on a spaced pair of ball bearings of the sealed-lubricant pattern; the two rows of balls with their retainers forms a single bearing unit which is located in the body by means of a set-screw.

When the pump has seen long service the face of the impeller body, against which the carbon seal bears and rotates, is liable to become scored or pitted, and it should be trued up before a new carbon seal is fitted.

Fig. 543 illustrates the method of truing up this face in the case of the Vauxhall and Bedford water pumps—the latter example is here considered. The carbon seal bearing face is trued by means of an abrasive stone and Black & Decker equipment, with spigot and pilot unit to ensure correct location and alignment. The cutting stone holder is rotated by hand whilst exerting end pressure so as to make it cut. Blue marking should be used to check that the face is trued correctly. Only the bare minimum of metal must be removed or the efficiency of the water seal will be impaired.

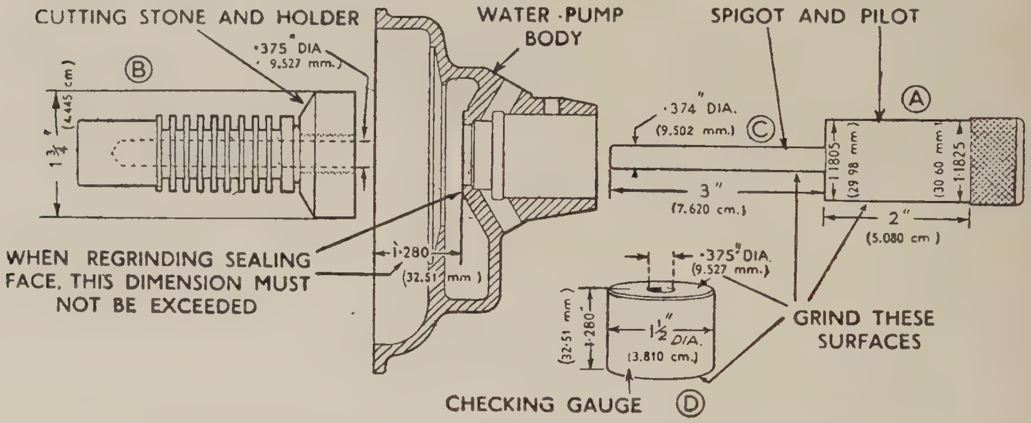


Fig. 543.—The Bedford Water-pump Body Servicing Method.
A—Pilot. B—Cutting Stone and Holder. C—Spigot to engage in (B). D—Checking Gauge for Distance.

Fig. 544 shows the A.E.C. 70-h.p. oil-engine water pump which uses carbon packing for sealing the pump shaft.

The centrifugal water pump, which is mounted on the forward face of the timing case, is driven by a dog from the auxiliary shaft. Packing of the usual kind is eliminated by the use of a special seating made of carbon against which runs a shoulder formed integral with the pump spindle.

Positive contact between the two is assured by a coil spring between the end of the spindle and the pump vane.

The pump spindle is of stainless steel and is carried on an extension of the auxiliary shaft with which it rotates so that no lubrication of any kind is required for this spindle.

The carbon seating is carried in a steel sleeve which is screwed into the

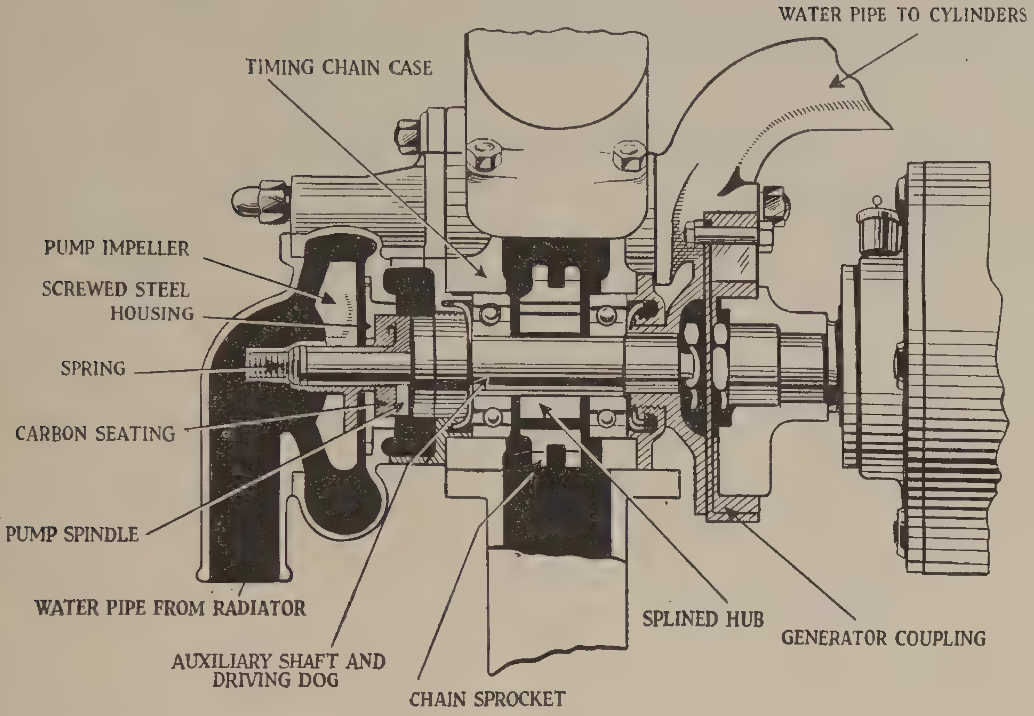


Fig. 544.—The A.E.C. Water-circulating Pump and its Drive.

pump body and which can be removed when it is necessary to fit a new carbon seating.

To Fit a New Carbon Seating.—Particular care is required in fitting the carbon seating.

To replace the carbon seating the following procedure must be adhered to if satisfactory results are to be obtained.

Unscrew the steel sleeve which carries the carbon seating and heat in oil until the old seating becomes easily removable. Do not attempt to chip out the old seating, as this will damage the recess, which is machined to very accurate limits.

Carefully clean out the recess and heat the sleeve over a gas ring until it turns a pale straw colour, when the new seating should be dropped in and pushed up home against the back of the recess. Allow the sleeve to cool in air and the seating will be tightly held in the recess. Screw the sleeve back into the pump body and fit the pump spindle. The seating is made slightly convex so that an even marking all round will be obtained quickly. A good seating $\frac{1}{8}$ in. wide all round will make an efficient gland, and as wear takes place the width of the seating increases.

Care should be taken when fitting the spindle so that the inner edges of the carbon seating are not chipped. Should chipping occur, it will be necessary to renew the seating.

When replacing the water pump on the engine, make sure that the spring is inserted in the hollow spindle.

Cooling System Faults and Causes

The various troubles likely to occur in motor-car and commercial-vehicle cooling systems may be summarised as follows:

(A) *Loss of Water from System*

Causes

(1) Fractured radiator upper or lower tank.
(2) Holding-down brackets fractured at radiator joint.
(3) Water tubes or elements leaking at one or more places.
(4) Leakage at rubber hose connections (due to old or perished hose at ends), or to hose clips not acting effectively or needing screwing up.
(5) Leakage at water-pump spindle gland.
(6) Leakage at cylinder-head gasket.
(7) Cracked water jacket in cylinder block or head.
(8) Loss of water due to persistent boiling in system.
(9) Drain tap not fully " off," or leaking.

(B) *Overheating of Engine*

Causes

(1) Ignition too far retarded or automatic ignition advance out of operation.
(2) Carburation setting incorrect. Mixture too weak or too rich.
(3) Insufficient water in cooling system.
(4) Partly choked water spaces in radiator.
(5) Fan belt slipping or fan blades at wrong angle. In some engines a right-hand fan may be fitted incorrectly for a left-hand fan used on earlier models, or vice versa.
(6) Thermostat opening only at appreciably higher temperatures than normal one, or refusing to open at all owing to damage or corrosion.
(7) External additional resistance to engine, e.g. binding brakes or badly adjusted back-axle gears.
(8) Slipping clutch causing reduced forward speed that is not sufficient for adequate radiator cooling.